NEW

EARTH UNCOVERED

JOURNEY THROUGH THE INCREDIBLE WORLD WE LIVE IN

Digital Edition

FUTURE

SECOND EDITION

WELCOME TO

EARTH UNCOVERED

Science has revealed a great deal about our planet, from how it formed and how it has evolved over billions of years, through to its current position in the universe. Although there is always going to be more to discover, right now we have a clearer picture of Earth than ever before.

Join us as we journey through the incredible world we live in, exploring its awesome landscapes and weather wonders, as well as its geological marvels and diverse wildlife.

Learn about extreme landscapes such as Antarctica, the Amazon rainforest and the African savannah, as well as features such as mountain ranges, meandering rivers, desolate deserts and coral reefs. Discover the scientific explanations behind weather phenomena including supercell storms and tornadoes, as well as the spectacular light shows of the aurora borealis. Understand how they occur and prepare to be amazed! Explore the planet's geology from volatile volcanoes and destructive earthquakes to incredible rock formations like The Wave of Arizona. Learn how fossils are created and how mysterious structures like the Eye of the Sahara appear. Finally, get to know some of the amazing creatures in the animal kingdom that share our planet, and examine how they have evolved over time, from primates and big cats to ocean giants and birds of prey.

Filled with breathtaking imagery and awe-inspiring facts, there is something for everyone in this stunning book.

This bookazine is printed on recycled paper. It's important that we care about our planet and make a difference where we can, for us and every generation that follows.

EARTH UNCOVERED

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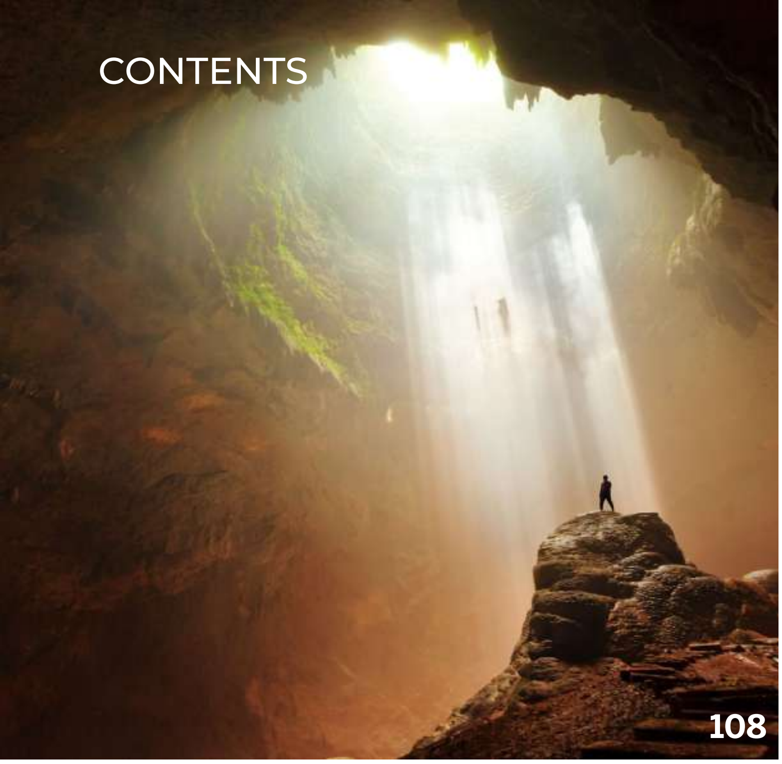

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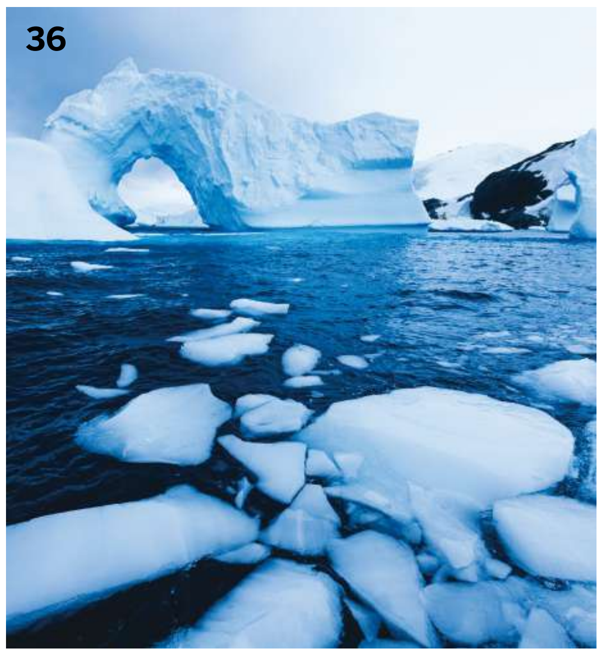

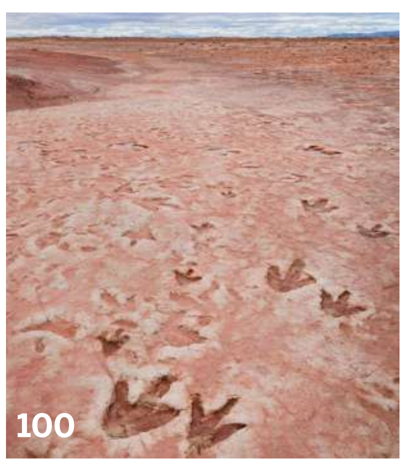

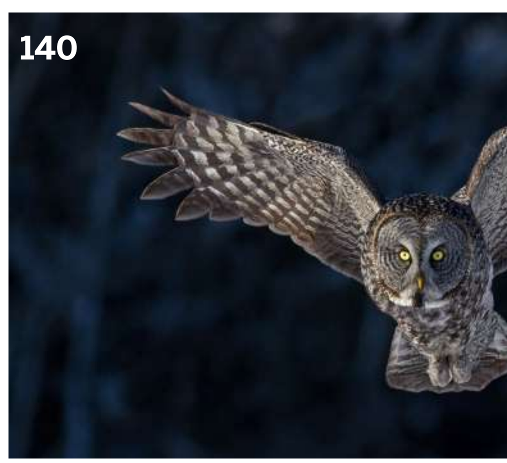

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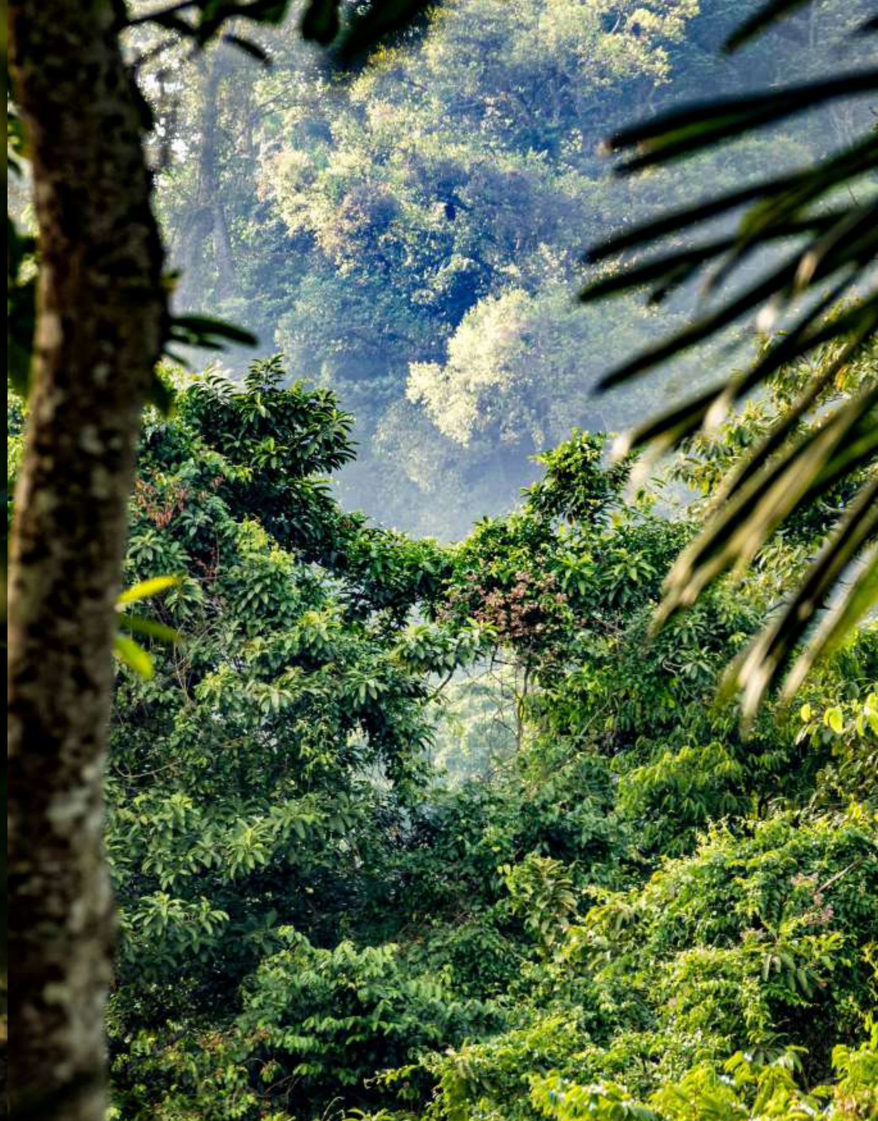
LANDSCAPES

LIFE IN THE RAINFOREST

The rainforest is a three-dimensional world, with multiple levels of wildlife to be found up its towering trees



Tropical rainforests are incredibly rich in wildlife. They cover about two per cent of Earth's surface, yet they are home to around half of all the known species of flora and fauna. In the year-round warm and wet conditions, plants can grow, flower and fruit nonstop. That allows trees to quickly reach great heights. In a typical rainforest, the treetops overlap to form a continuous green layer called the canopy, about 45 metres (150 feet) above ground level. A few trees, called emergents, project well above this canopy – the tallest reaching over 80 metres (260 feet) high.

The dense canopy of leaves blocks most sunlight from reaching the ground, where it is shady, damp and dank. For a visitor expecting to see a jungle full of colourful birds and monkeys, the rainforest floor is disappointing. A few small mammals do scurry about here, feeding on fruit that's dropped from above, but they are mostly shy and secretive. Wild cats, like ocelots and jaguars, hunt them – mainly at night – but these are even more difficult to spot.

Life on the forest floor is mostly small and hidden. Dead animals, broken branches and even whole trees from above are the food for myriad insects, worms and fungi. Along with bacteria, these decomposers play a vital role, breaking down the detritus and releasing minerals and nutrients back into the soil to nourish new life in a perpetual cycle.

"THE AMAZON SPANS NINE COUNTRIES & CONTAINS ALMOST 400 BILLION TREES"

The Amazon biome spans nine countries and contains almost 400 billion trees of 16,000 different species. It's a complex web of many ecosystems, including rainforests, savannahs, swamps, grasslands and flood plains. Despite covering roughly one per cent of Earth's surface, the Amazon is home to around ten per cent of all known species. It's incredibly biodiverse; there are more ant species on one tree in the Amazon Rainforest than there are in some countries!

The health of the Amazon is directly linked to the health of our planet. The trees that form it release around 20 billion tons of water as vapour every day, which brings rain to the continent. The rainforests contain 90-140 billion metric tons of carbon – which would otherwise be emitted into the atmosphere – and help to stabilise the world's climate. Deforestation is one of the many threats the Amazon faces, and it could result in the release of some of this carbon, which would dramatically accelerate global warming.

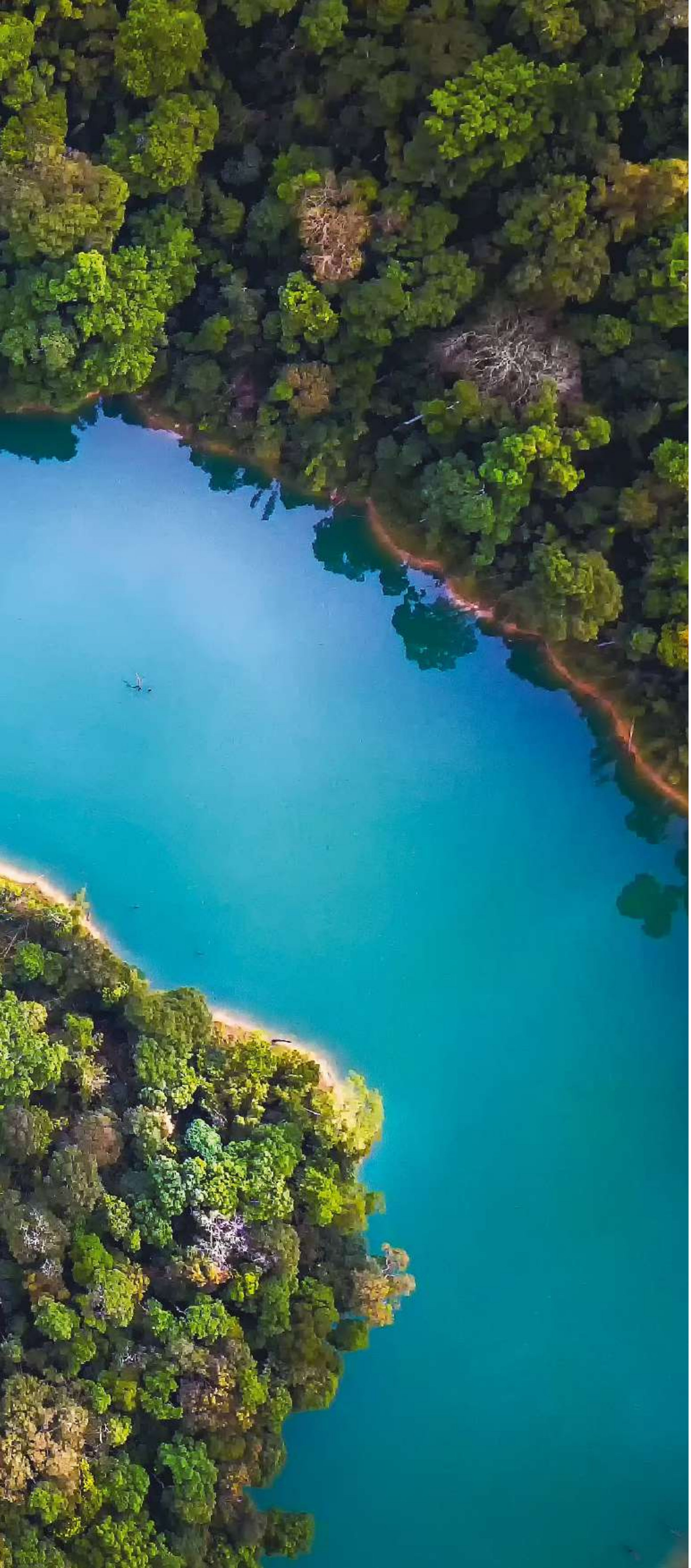
ABOVE
The Amazon is the world's longest river, running through the rainforest

TOP LEFT, CLOCKWISE
Jaguars are one of the many animal species found in rainforests

Nine countries have the Amazon rainforest within their borders

Guarana, in the Amazon basin, has twice as much caffeine as a coffee bean

San Rafael Falls, Ecuador's largest waterfall, cuts through cloudy rainforest



RIVERS

How the mighty river runs its course and brings life to the basin, from source to sea

Beginning life in the mountains, rivers form from streams created through precipitation or springs of water that are sourced from groundwater that has percolated the earth. These streams, known as tributaries, then flow rapidly through V-shaped valleys, over rocky terrain and over rock edges as waterfalls. This is the first of three stages any river goes through and is known as the upper course or youth.

By the second stage, known as the middle course or maturity, many tributaries will have joined together to form the main body of water that makes up the river. The river meanders at a medium speed across narrow flood plains, which are areas of flat land lying either side of a river. Flood plains are formed when successive flooding causes sediment to be deposited on the banks.

As the river follows its course, it carries with it a load, which is made up of rocks, stones, sand and other particles. It is the load that causes erosion as the materials crash against the banks of the river. The load is transported down the river in four ways, depending upon the size of the material. Traction is the rolling of the largest particles across the riverbed, whereas saltation is the bouncing of those slightly smaller. Finer materials are carried along through suspension and some are dissolved within the water and are moved through solution.

The final stage of a river is the lower course, sometimes known as 'old age'. By this time the river has slowed down considerably as it heads towards the sea across broad flood plains, finally ending at what is known as the mouth – where the river finally joins the ocean. Deltas are formed as the river deposits its load.

"AS THE RIVER FOLLOWS ITS COURSE, IT CARRIES WITH IT A LOAD, WHICH IS MADE UP OF ROCKS, STONES, SAND AND OTHER PARTICLES"

LEFT
Rivers are a crucial resource for vegetation and wildlife

WATERFALL WONDERS

How water's sheer power creates a natural spectacle

Big waterfalls are among the most spectacular and energetic geological features on Earth. The thundering waters of Niagara Falls can fill an Olympic-sized pool every second. Visitors are drenched with spray and deafened by volumes reaching 100 decibels, equivalent to a rock concert.

A waterfall is a river or stream flowing down a cliff or rock steps. They commonly form when rivers flow downhill from hard to softer bedrock. The weak rock erodes faster, steepening the slope until a waterfall forms. The Iguazú Falls on the Argentina-Brazil border, for example, tumble over three layers of old resistant lava onto soft sedimentary rocks.

Any process that increases the gradient can generate waterfalls. A 1999 earthquake in Taiwan thrust up rock slabs along a fault, creating sharp drops along several rivers. A series of new waterfalls appeared in minutes, some up to seven metres (23 feet) high – taller than a double-decker bus.

Many waterfalls were created by rivers of ice during past ice ages. These glaciers deepened big valleys, such as Milford Sound in New Zealand. The ice melted and shallow tributaries were left 'hanging' high above the main valley. Today the Bowen River joins Milford Sound at a waterfall 162 metres (531 feet) high, almost as tall as the Gherkin skyscraper in London.

Waterfalls vary enormously in appearance. Some are frail ribbons of liquid while others are roaring torrents. All waterfalls are classed as cascades or cataracts. Cascades flow down irregular steps in the bedrock, while cataracts are more powerful and accompanied by rapids.

Gigantic waterfalls seem ageless, but they last only a few thousands of years – a blink in geological time. Debris carried by the Iguazú River is slowly eroding the soft sediments at the base of the falls, causing the lava above to fracture and collapse. Erosion has caused the falls to retreat 28 kilometres (17 miles) upstream, leaving a gorge behind.

The erosional forces that birth waterfalls eventually destroy them. In around 50,000 years, there will be no Niagara Falls to visit. The Niagara River will have cut 32 kilometres (20 miles) back to its source at Lake Erie in North America and disappeared.

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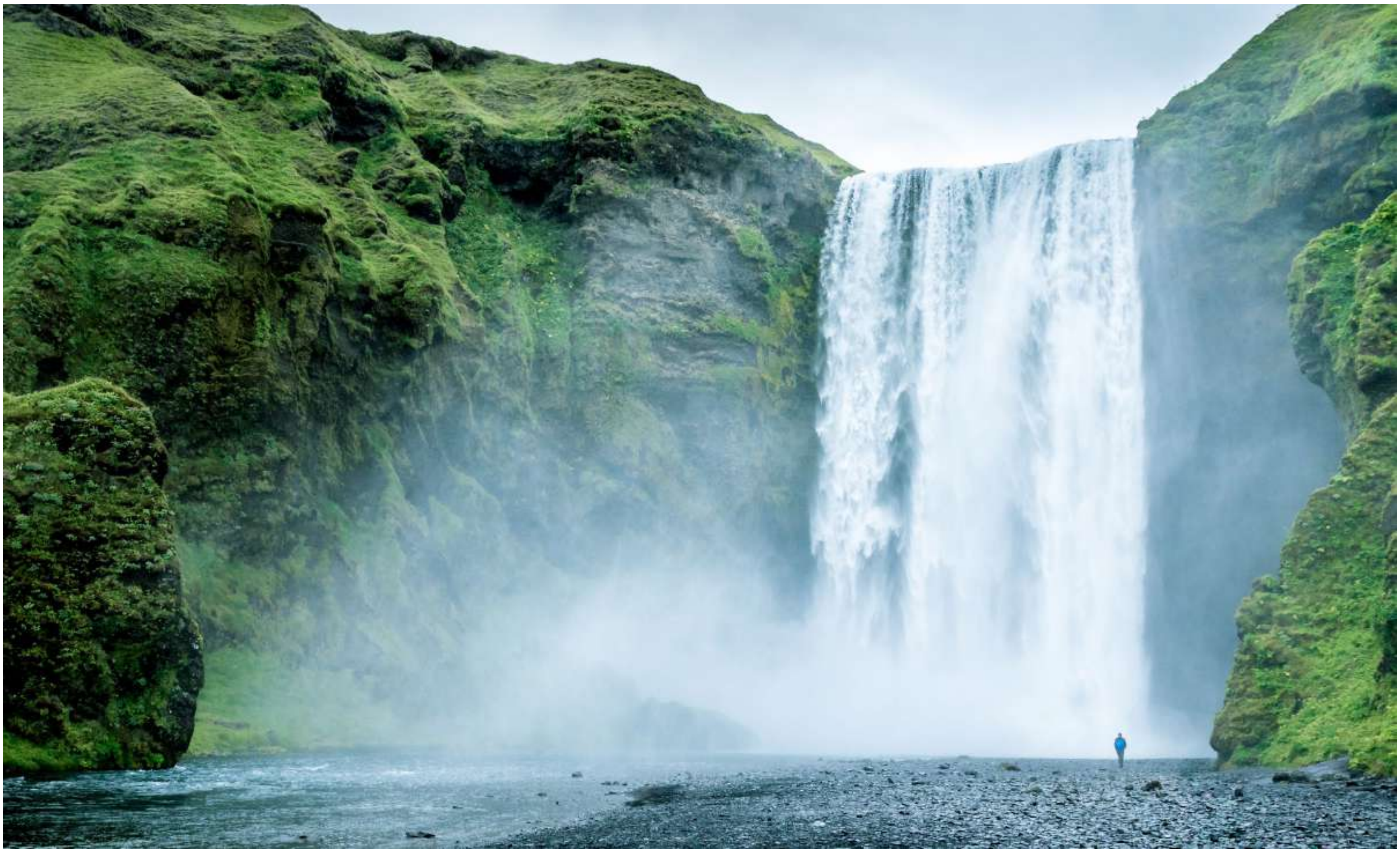
Over 3,000 tons of water flow from Niagara Falls (pictured) every second



ABOVE
Skógafoss in Iceland formed when the coastline receded

LEFT
Angel Falls, Venezuela, is the world's highest uninterrupted waterfall

"PEOPLE HAVE LONG DREAMED OF HARNESSING THE POWER AND ENERGY OF THE BIGGEST FALLS"

The sheer force and power of waterfalls makes them impossible to ignore. Daredevils across the centuries have used them for stunts. The first tightrope walker crossed the Niagara Falls in 1859. Risk-takers have ridden the falls on jet skis, in huge rubber balls or wooden barrels and many have died. The steep drops mean waterfalls often pose a navigation problem. In the 19th century, the Welland Canal was built to bypass Niagara Falls.

People have long dreamed of harnessing the power and energy of the biggest falls. The first recorded attempt to use the swift waters above Niagara, for example, was in 1759 to power a water wheel and sawmill. Today many hydroelectric plants generate electricity near big waterfalls, such as the Sir Adam Beck Power Plants above Niagara Falls. River water is diverted downhill past propeller-like turbines. The rushing flow spins the turbine blades, creating renewable electricity. The bigger the drop, the faster the water, and the more energy it contains as a result.

Harnessing rivers for electricity can conflict with the natural beauty of their waterfalls. The Guaíra Falls on the Paraná River, probably the biggest waterfall by volume, were submerged in the 1980s by the building of the Itaipu hydroelectric dam.

These days, the conflict between power and nature is greater than ever. Dr Ryan Yonk is a professor of political science at Southern Utah University. According to him, "the demand for electricity generation in the developing world is not going away and it's going to ramp up."

Controversial hydroelectricity projects, like some in Asia, involve a trade-off between beauty and tackling climate change. Dr Yonk believes "the alternatives in those countries are likely to be very dirty coal."

Above Niagara Falls, treaties have balanced energy generation with iconic scenery since 1909. During the summer, when most of the 12 million annual tourists visit, about half the water carried by the river must flow over the falls – an incredible 2,832 cubic metres per second (100,000 cubic feet per second).

Yet these summer flow limits have a price. One study says the loss of potential electricity from the current treaty is 3.23 million megawatt hours each year – enough to run four million light bulbs.

Withdrawing more water could have benefits above hydropower generation. Samiha Tahseen is a civil engineering PhD student, studying Niagara flow at the University of Toronto. According to her, "you can reduce the erosion of the falls."

Another advantage to limiting flow in waterfalls is minimising the problem of mist obstructing the view. Samiha adds: "There is no denying that the mist is dependent on the flow so if you decrease the flow of the falls a little bit, that helps."

WHITE-WATER RAPIDS

Discover the part of a river's course that provides the world's most dangerously turbulent - but thrilling - water

White water occurs in the upper course of the river when the gradient and obstacles disturb the flow of water, causing it to churn and create bubbles. These bubbles reflect back much of the light that hits them, making the water appear white. Whether a river flows smoothly often depends on its speed, and the steeper the riverbed, the faster the water will flow.

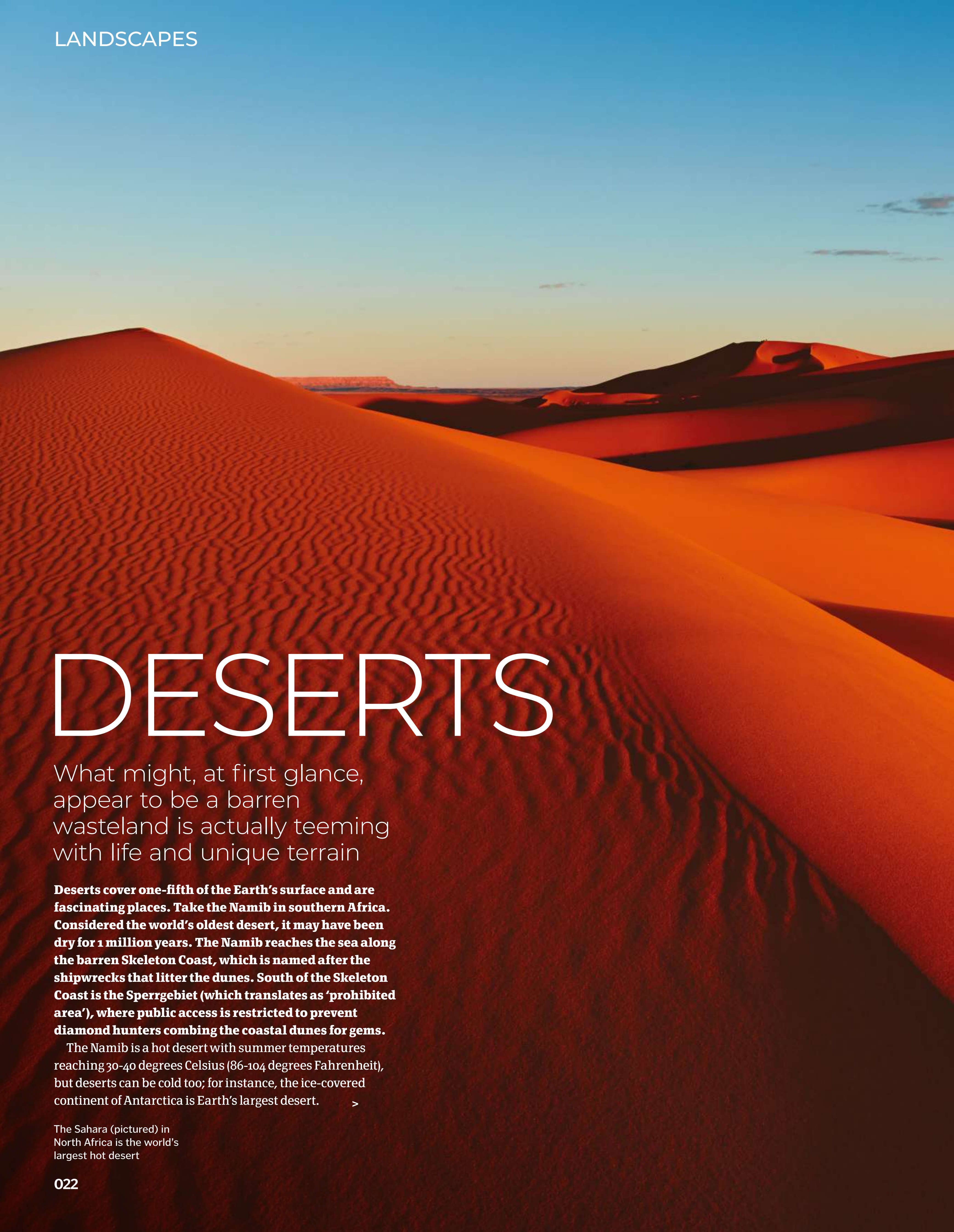
The combination of fast-flowing water and obstacles like rocks causes the flow to become turbulent, with unpredictable variation in the speed and direction of the water. This creates a variety of features in the river. Where water doubles back on itself, pockets filled with bubbles open up; these provide much less buoyancy and feel like 'holes'. Objects lodged in the river, like trees, can act as strainers, allowing water to pass through, but blocking the passage of larger debris. And in areas where the water moves rapidly, it wears away at the surface of rocks underneath, creating undercuts.

The challenges of navigating the variable features of white-water rapids – whether they be jutting rocks, whirlpools or pressure waves – attract thousands of adrenaline-junkie kayakers and rafters every year.

LEFT
The Huka Falls is actually a series of waterfalls, which drop over 11 metres (36 feet) on the Waikato River in New Zealand

BELOW
Kayakers grade rapids into classes based on their difficulty to navigate

"THE COMBINATION OF FAST-FLOWING WATER AND OBSTACLES CAUSES THE FLOW TO BECOME TURBULENT"



DESERTS

What might, at first glance, appear to be a barren wasteland is actually teeming with life and unique terrain

Deserts cover one-fifth of the Earth's surface and are fascinating places. Take the Namib in southern Africa. Considered the world's oldest desert, it may have been dry for 1 million years. The Namib reaches the sea along the barren Skeleton Coast, which is named after the shipwrecks that litter the dunes. South of the Skeleton Coast is the Sperrgebiet (which translates as 'prohibited area'), where public access is restricted to prevent diamond hunters combing the coastal dunes for gems.

The Namib is a hot desert with summer temperatures reaching 30-40 degrees Celsius (86-104 degrees Fahrenheit), but deserts can be cold too; for instance, the ice-covered continent of Antarctica is Earth's largest desert. >

The Sahara (pictured) in North Africa is the world's largest hot desert

A desert is simply a place where average rainfall is less than 0.5 metres (1.6 feet) per year. Indeed, some deserts remain rainless for months or even years.

Most of Earth's hot deserts lie within 30 degrees latitude of the equator. Examples include Africa's vast Sahara Desert. Gigantic atmospheric currents force air to sink and warm at these latitudes, which in turn suppresses rainfall.

The Namib and Atacama are coastal deserts lying beside cold ocean currents – the Benguela and Peru Currents, respectively – that cause air above them to cool. Cold air can hold less water, reducing the rain falling on nearby warm land. These deserts are among Earth's driest. Most moisture here comes from desert fogs, which form when warm air condenses over the cold ocean.

Some deserts in central Asia and Australia lie in continental interiors, so damp ocean air loses most of its moisture before it can reach them.

Desert climates and wildlife vary drastically. Hot deserts like the Sahara are warm year-round and rain is scarce. Temperatures can reach 49 degrees Celsius (120 degrees Fahrenheit) during the day, but at night can plunge to -18 degrees Celsius (-0.4 degrees Fahrenheit). Clear skies allow heat to escape after sunset and small mammals forage at dusk. Plants include ground-hugging shrubs with leathery leaves.

"DESERT CLIMATES AND WILDLIFE VARY DRASTICALLY. HOT DESERTS LIKE THE SAHARA ARE WARM YEAR-ROUND"

In semi-arid deserts, like the US Great Basin's sagebrush, temperatures rarely fall below ten degrees Celsius (50 degrees Fahrenheit) or rise above 38 degrees Celsius (100 degrees Fahrenheit). Spiny plants like the creosote bush thrive here.

Close to cold ocean coasts, desert summer temperatures rarely rise above 24 degrees Celsius (72 degrees Fahrenheit) and yearly rainfall can be 13 centimetres (five inches). Plants have roots close to the surface to collect rain and fleshy, water-storing stems. Some toads remain dormant in burrows for months between rainstorms.

Desert ecosystems are damaged by things like off-road vehicles, drilling and mining. Higher temperatures due to climate change could threaten drought-adapted wildlife by increasing fires as well as drying out waterholes.

ABOVE
The Namib Desert ends at the Skeleton Coast, lying by the Atlantic Ocean

OASES

Deserts might be notoriously dry places, but fertile oases can prevail there and even support wildlife, towns and villages

An oasis is a fertile area in an otherwise barren desert region. Groundwater flows beneath the surface of the Earth – even in the deserts, where rainfall is scarce – and if you drill straight down, you'll eventually reach the water table. Occasionally, this water table rises until it's near or just above the surface of the Earth, which can either produce moisture within the soil or create a freshwater pool that allows life to flourish.

Water tables are rarely level, instead sloping in relation to the type and porosity of the rock in an area. The hilly nature of desert dunes means the water table occasionally intersects the surface of the land. Strong desert winds can displace vast amounts of sand and lower the elevation of the land until it falls below the water table, resulting in pools of fresh water above ground.

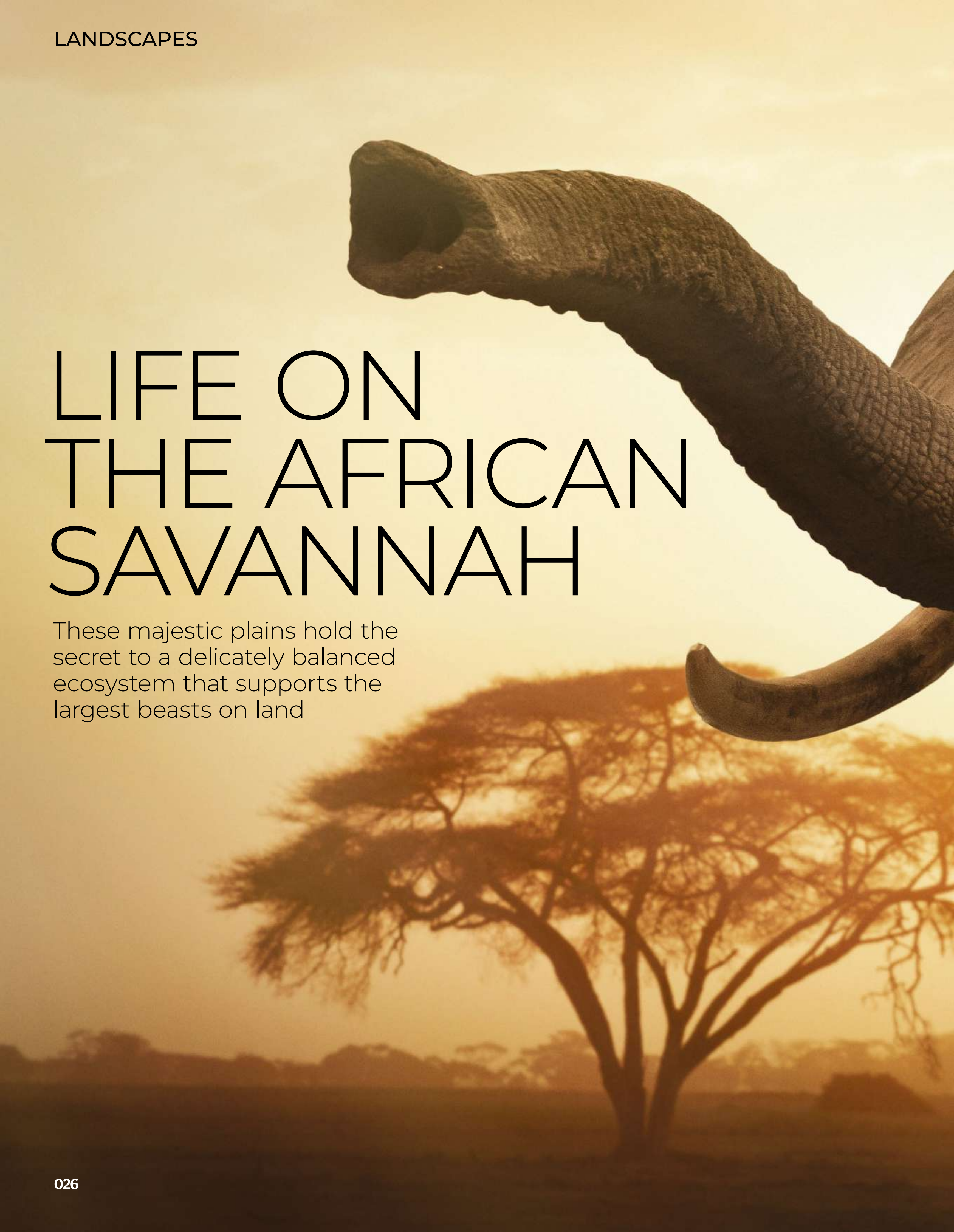
An aquifer is a layer of water-bearing rock within the groundwater. As a water source, an aquifer can also emerge as a natural spring that can irrigate an area, enabling vegetation to thrive and travellers to tap a fresh water supply.

Artificial oases are often built to support civilisations, using wells that can tap down into aquifers and pump fresh water up to the surface.

There are a number of oases in the Sahara Desert such as Ubari (shown)

LIFE ON THE AFRICAN SAVANNAH

These majestic plains hold the secret to a delicately balanced ecosystem that supports the largest beasts on land



ABOVE
Exotic wildlife, such as giraffes and venomous snakes, freely roam

"WHEN YOU THINK OF THE WORD 'SAVANNAH', ROLLING AFRICAN GRASSLANDS COME TO MIND"

The savannah environment is a huge expanse of wide-open grassland that is home to a web of incredible plants and animals. Formed exclusively around the tropics, savannahs are characterised by just enough rainfall in the wet season to enable plants to flourish, yet not enough for a rainforest, and almost arid conditions in the dry season, but not dry enough to form a desert. The plants and animals that live here have developed amazing means of coping with this extreme environment.

Around the world, savannahs are known by different names; in Asia they are 'steppes', they are 'prairies' in North America, and in Australia they are 'rangelands'. Usually only African grasslands are given the name 'savannah', and one of the most famous is the Serengeti Plains in Tanzania. This ecosystem is home to some of Earth's most incredible creatures: big cats, elephants, rhinos and giraffes to name just a select few.

When you think of the word 'savannah', rolling African grasslands come to mind, along with Mufasa's words to Simba: "Everything the light touches is our kingdom." Disney's classic cartoon actually portrays an ecosystem that is very real. Africa's most famous savannah regions encompass the Serengeti National Park, the Ngorongoro Conservation Area, Maswa Game Reserve, the Loliondo, Grumeti and Ikorongo Controlled Areas and the Maasai Mara National Reserve. So important is the 30,000 -square-kilometre (11,580-square-mile) region, that it contains two World Heritage Sites and two Biosphere Reserves.

The savannah biome has two distinct seasons, wet and dry, but there is still too little rain for many trees to grow, and so grasses and shrubs dominate the ecosystem. These hardy plants are able to support the great migration of herds of herbivorous animals, such as zebra and wildebeest, which travel en masse, chasing the rains and spurred on by the growth of new grass. Hungry predators like lions and cheetahs anticipate the arrival of these herds.

The savannah temperature remains fairly constant, and water holes can be found at various points across the plains (depending on the season), where many animals will gather to take a drink. The rainy season stretches from around November to May, and then the dry season sets in and temperatures remain around 27 degrees Celsius (81 degrees Fahrenheit).

The hoards of wildebeest, zebra and gazelle aren't the only animals willing to make a trek to find water. Elephants, living in their close-knit familial groups, can locate water holes up to 50 kilometres (31 miles) away in a relatively featureless environment. It's thought that they have excellent spatial memories, and can use this to recall where

the water holes are in this radius. Safari goers to these regions have also noticed large ruts in the earth – this is caused by elephants using their long, strong tusks to dig down into the soil to search for water or to eat the soil to take in valuable nutrients.

Grasses are the prime source of food for the elephants and with so many other grazers, such as antelope and even rhinos, it's difficult to see how the grass doesn't simply wear out. The secret to this lies in both the grasses' biology and in the niches filled by each animal. Constant cutting of common savannah grass species, such as red grass or elephant grass, actually promotes fresh growth. This is because the grass growth occurs from the bottom of the shoot, so while they're nibbling away, the creatures are also gradually cultivating a grazing lawn. Different types of animals also have their own feeding techniques and take greenery from various levels. For example, giraffes browse for shoots, leaves and buds from high up in the trees, while zebras graze on the savannah floor. This means that there is little competition when it comes to finding vegetarian food.

Another rather more curious way that savannah grasses stay in healthy balance is through fire. During the dry season wildfires are a common occurrence and can burn away huge patches of grassland. However, instead of being devastating, these fires can return much-needed nutrients to the soil and encourage new growth. Many plant species are fireproof and can withstand the flames, and the fires also help to keep encroaching forests from taking over the grassland.

The hunters of the savannah are the big cats that sit at the very top of the food chain. Lions are, of course, the kings of the plains, but leopards, cheetah and African wild dogs are also high up in the savannah court. When the migratory herds arrive it provides rich pickings for these stealthy predators, who ensure that only the fittest prey survive. And where there are predators, there are scavengers, lurking on the sidelines. Spotted hyenas are skilful hunters but they're not picky eaters and will happily feast on the leftovers of other kills, as well as clean up any natural deaths. A very tough digestive tract enables the hyena to devour just about anything they find, and items that can't be digested are swiftly regurgitated.

The large animals are just tiny cogs in the giant wheel that keeps the savannah biome in balance. Of equal importance are the smaller creatures and tiny insects that work the savannah soil and decompose the waste to recycle nutrients.

Humans also flourish on these grasslands. Tribes such as the Maasai have lived and farmed there for many thousands of years, as the soil facilitates the growth of cereal crops and the grazing of cattle. While we worry about garden invaders like foxes, the Maasai are more concerned about elephants trampling and eating their produce! They are a culture steeped in tradition and have a strong bond with the land.

BELOW
Savannahs can look drastically different depending on the season

MOUNTAINS

How many ways can you make a mountain?

Mountains are massive landforms rising high above the Earth's surface, caused by one or more geological processes: plate tectonics, volcanic activity and/or erosion. Generally they fall into one of five categories – fold, fault-block, dome, volcanic and plateau – although there can be some overlap.

Mountains comprise about 25 per cent of our land mass, with Asia having more than 60 per cent of them. They are home to 12 per cent of the Earth's population, and they don't just provide beauty and recreation; more than half of the people on Earth rely on the fresh water that flows from the mountains to feed streams and rivers. Mountains are also incredibly biodiverse, with unique layers of ecosystems depending on their elevation and climate.

One of the most amazing things about mountains is that although they look solid and immovable to us, they're always changing. Mountains rising from activity associated with plate tectonics – fold and fault-block – form slowly over millions of years. The plates and rocks that initially interacted to form the mountains continue to move up to 2cm (0.7in) each year, meaning that the mountains grow. The Himalayas, for example, grow about 1cm per year.

The volcanic activity that builds mountains can wax and wane over time. Mount Fuji, the tallest mountain in Japan, has erupted 16 times since 781 CE. Mount Pinatubo in the Philippines erupted in the early 1990s without any prior recorded eruptions, producing the second largest volcanic eruption of the 20th century. Inactive volcanic mountains – and all other types of mountains, for that matter – are also subject to erosion, earthquakes and other activity that can dramatically alter their appearances as well as the landscape around us. There are even classifications for the different types of mountain peaks that have been affected by glacial periods in Earth's history. The bare, near-vertical mountaintop of the Matterhorn in the Alps, for example, is known as a pyramidal peak, or horn.

ABOVE
Mount Fuji in Japan is one of the world's most picturesque volcanoes

LEFT
The Matterhorn at 4,478 metres stands alone on the Swiss-Italian border

THE PYRENEES

Discover how an ancient European mountain range came back from the dead to form a high-altitude natural barrier between France and Spain

The Pyrenees stretch from the Mediterranean Sea to the Bay of Biscay in the Atlantic Ocean. This huge mountain chain has acted as a natural barrier throughout human history, separating Spain and Portugal from the rest of Europe. The Spanish and French slopes both have different climates and are home to over 3,500 plant and animal species, including brown bears.

The story of the Pyrenees begins more than 500 million years ago when the ancient Hercynian mountains covered much of central Europe. This vast range was comprised of sedimentary rocks folded over granite bedrock.

Over millions of years, these mountains were worn down by rivers, wind, frost and ice. At the same time, the jigsaw of tectonic plates that make up the Earth's crust were drifting across our planet's surface. As a result, new oceans opened up. The region containing today's Pyrenees became the Pyrenean basin – a low-lying area between France and Spain often submerged under the sea. Sediment gathered on the seafloor above the old Hercynian range, eventually becoming new sedimentary rock.

Around 85 million years ago – towards the end of the age of the dinosaurs – the crustal plate that carries Spain moved northwards. This closed the gap between the Mediterranean Sea and the Bay of Biscay, compressed the Pyrenean basin sediments and fractured the Hercynian rocks. The younger sediments folded like modelling clay into new peaks and the Pyrenees emerged.

Since then, the young rocks have worn away in places to reveal the ancient rocks beneath. During the last ice age – approximately 20,000 years ago – rivers of ice flowed down the mountain valleys. These glaciers picked up rocks as they went, grinding and scraping the surface below like sandpaper. Over time, they carved out bowl-shaped hollows called cirques and U-shaped valleys. Today, the Pyrenees continue to be eroded by rivers and frost shatter, especially at higher altitudes.

© Getty

FJORDS

These spectacular valleys may look peaceful, but their formation was anything but

Fjords are long, steep-sided coastal valleys that are flooded by the sea. The majority of fjords developed during the last ice age, peaking approximately 20,000 years ago. Glaciers dominated the landscape, snaking their way to the ocean and tearing through anything that stood in their path. These massive valleys are typically found in mountainous, coastal areas of the Atlantic and Pacific oceans, and are common in Norway, Sweden, Greenland, Canada, Chile, New Zealand and the US state of Alaska.

As a glacier carved its way through the rock, it cut a distinctive U-shaped valley. The floor was flat and the sides were steep and high. As the massive river of ice – which could reach up to three kilometres (1.9 miles) thick – bore through the valley floor, it picked up rocky debris and carried it along for the ride, adding to the glacier's rock-shattering abrasive power. This rubble eventually made its way to the head of the glacier and was pushed in front of it as the glacier travelled – known as a terminal moraine. Such is the sheer power of the glacier to gouge out rock that the bottoms of fjords are often deeper than the ocean that they open into. For example, the deepest point of the Sognefjord in Norway is approximately 1,300 metres (4,265 feet) below sea level whereas the sill is just 100 metres (328 feet) below sea level. As the ice age came to a close, the oceans flooded into these extra-deep glaciated valleys, forming what we now know as fjords.

It's the rock formations of a glaciated landscape that are left for us to see today. The glacial moraine will still be present at the entrance of a fjord – a large sill acting as a barrier between fjord and open ocean. There are also other features such as skerries, which are rocky islands within a fjord that can be both large and mountainous or small and treacherous to navigate in a boat.

Norway has over a thousand fjords, such as Sunnylvsfjorden (shown)

ANTARCTICA EXPLORED

What's large, hostile and used to trial missions to Mars? Antarctica – the world's coolest continent

Antarctica is the world's last great wilderness and Earth's coldest, windiest, highest and driest continent. Around 98 per cent of the land area lies buried beneath kilometres of snow and ice, yet Antarctica is – paradoxically – a desert.

In fact, it is so inhospitable and remote that no one lives there permanently, despite it being 25 per cent bigger than Europe. This frozen continent remained relatively unexplored until the 19th century. Unveiling its mysteries claimed many lives.

Antarctica is definitely worth a visit from your armchair, however, because it may also be Earth's quirkiest and most remarkable continent. Among its marvels is a river that flows inland, Mars-like valleys where NASA scientists test equipment for space missions, and perpetually dark lakes where bacteria may have survived unchanged since Antarctica had lush forests like the Brazilian rainforest. Living in and around the Southern Ocean that encircles Antarctica are fish with antifreeze in their blood, the world's biggest animal, and a giant penguin that survives nine weeks without eating during the harsh Antarctic winter.

Antarctica is the chilliest place on Earth. At the Russian Vostok scientific research station in the cold, high continental interior, it can get cold enough for diesel fuel to freeze into icicles – even in summer. Vostok is the site of the coldest temperature ever recorded on Earth – an amazing -89.2 >

"THE CONTINENT IS ALSO EARTH'S WINDIEST"

degrees Celsius (-128.6 degrees Farenheit). The temperature in most freezers is only about -18 degrees Celsius (-0.4 degrees Farenheit).

The continent is also Earth's windiest. Antarctica's ice cools the overlying air, which makes it sink. This cold, heavy air accelerates downhill, creating wind gusts of over 200 kilometres (124 miles) an hour. The sinking air at Vostok is so dry that some scientific researchers pack hospital IV (intravenous) drip bags to stop becoming dangerously dehydrated. Few clouds can form in the dry air, and most moisture falls as snow or ice crystals. Any snow that falls accumulates, because it can't melt in the cold.

If the climate wasn't harsh enough, Antarctica never sees daylight for part of the winter because the sun barely rises over the horizon. Even in summer, the Sun is feeble and low in the sky. The extreme cold partly explains why two huge ice sheets cloak Antarctica. The white ice cools it further by reflecting away about 80 per cent of incoming sunlight. Together, these ice sheets contain around 70 per cent of the world's fresh water. If they melted, global sea levels would rise by 70 metres (230 feet) and swamp many of the world's major cities.

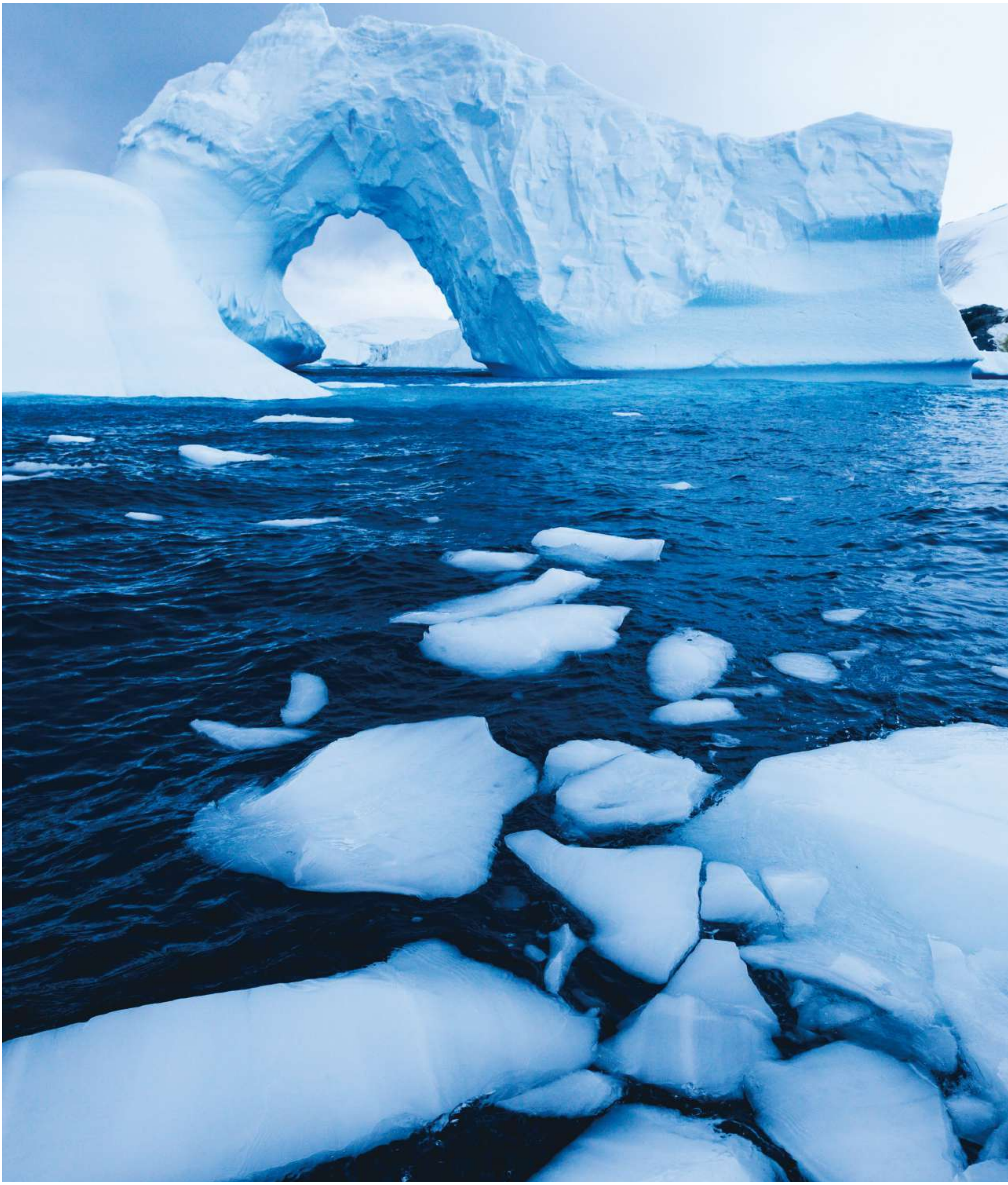
The East Antarctic ice sheet is the largest on Earth, with ice more than three kilometres (two miles) thick in places. Under the ice sheet are some of the oldest rocks on Earth – at least 3,000 million years old. The West Antarctic ice sheet is smaller, and drained by huge rivers of ice or glaciers. These move slowly in Antarctica's interior, but accelerate to up to 100 metres (328 feet) per year towards the coast. The fastest is Pine Island glacier, which can flow at more than three kilometres (two miles) per year. When these glaciers hit the sea, they form huge, floating sheets of ice attached to the land called 'ice shelves'. The biggest is the Ross Ice Shelf, which covers approximately the area of France.

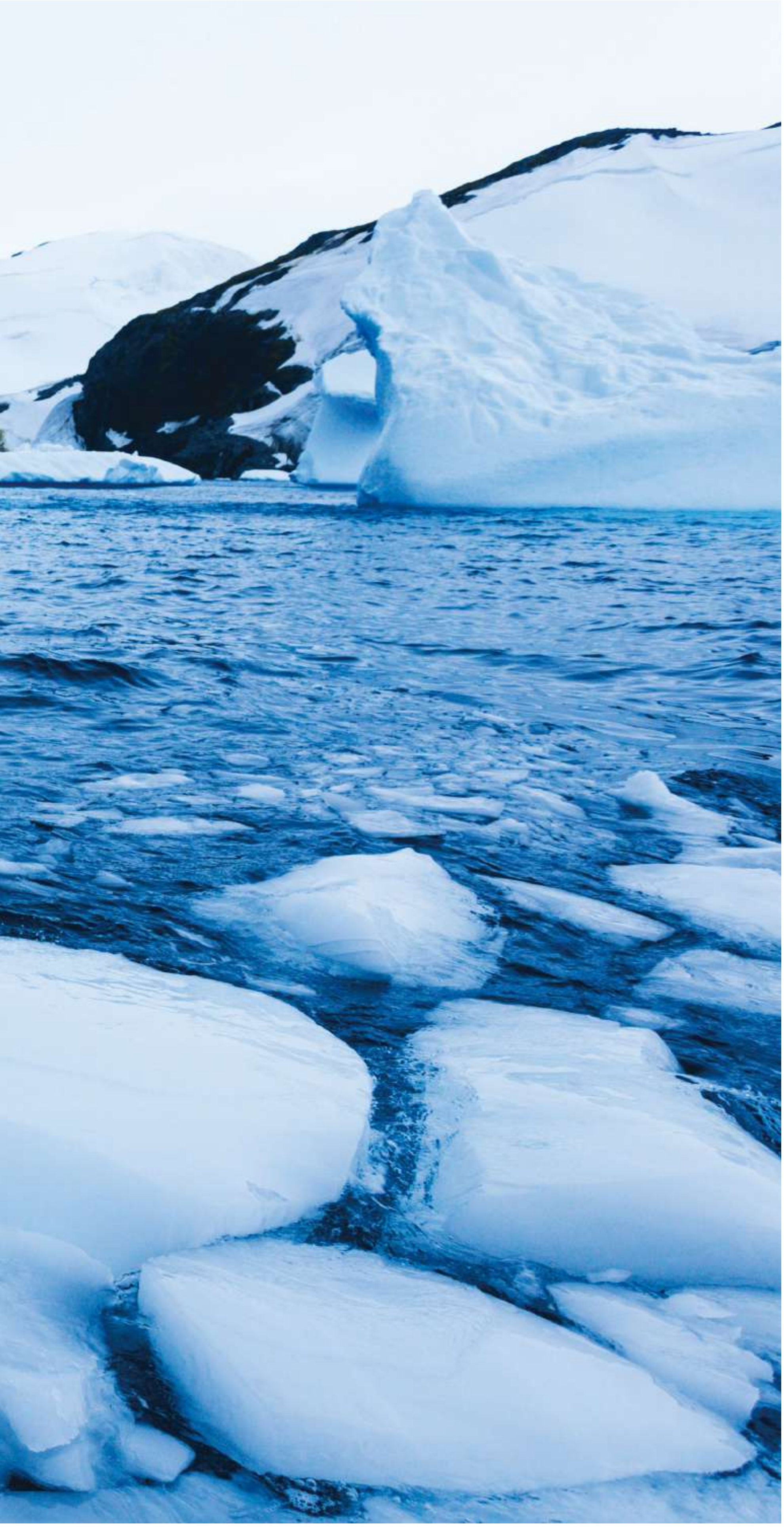
One of the world's biggest mountain ranges separates the two ice sheets. The Transantarctic Mountains are more than two kilometres (1.2 miles) high and 3,300 kilometres (2,051 miles) long – more than three times the length of the European Alps. The mountains were formed around 55 million years ago during a period of volcanic and geological activity. Volcanoes like Mount Erebus are still active today.

Antarctica's main ice-free area is the McMurdo Dry Valleys, a region with conditions like Mars through which runs the continent's longest, largest river. The Onyx River carries summer meltwater 40kilometres (25 miles) inland from coastal glaciers to feed Lake Vanda, which is saltier at its bottom than the Dead Sea. The salinity of Dry Valley lakes like Lake Vanda allows their deep water to stay liquid at >

ABOVE
Sea lions and King Cormorants rest on an isle in the Beagle Channel

RIGHT
A small group of penguins stand on the edge of a marooned iceberg





temperatures below the freezing point of fresh water. Other strange Antarctic lakes include Lake Untersee in the East Antarctic interior, which has water with the alkalinity of extra-strength laundry detergent.

Despite the harsh conditions and lack of soil, animals and plants survive on ice-free parts of Antarctica. In the windswept Dry Valleys, lichens, fungi and algae live in cracks in the rocks. Towards the coast, on islands and the peninsula, mosses are fed on by tiny insects, including microscopic worms, mites and midges. Some insects called springtails use their own natural antifreeze, so they can survive temperatures of less than -25 degrees Celsius (-13 degrees Farenheit). There are even two species of flowering plants.

In contrast, the Southern Ocean surrounding Antarctica is among the richest oceans in the world. The annual growth and melting of sea ice dredges nutrients from the ocean depths, resulting in phytoplankton. A single litre of water can contain more than a million of these tiny plants. The phytoplankton are eaten by krill – tiny shrimp-like creatures that are the powerhouse of Antarctica's ecosystem and feed most of its predators, including seals, fish, whales and penguins. They form dense swarms, with more than 10,000 krill in each cubic metre of water. Some swarms extend for miles and can even be seen from space. Alarming recent studies show that krill stocks have fallen by 80 per cent since the 1970s, probably due to global warming.

All of Antarctica's species are adapted to the extreme cold. Seals and whales have a thick layer of blubber for insulation and penguins have dense, waterproof plumage to protect them from salty, surface water at a frigid -1.8 degrees Celsius (29 degrees Farenheit). Some species of fish have antifreeze in their blood. Antarctic icefish have transparent blood and absorb oxygen through their skin.

The most common birds are penguins. Of the 17 species of Antarctic penguins, only two live on the continent itself. One is the world's largest penguin, the emperor penguin, which grows to 115 centimetres (four feet) tall. Being large helps it to keep warm. Emperor penguins breed on Antarctica's sea ice during the cold, dark winter, enduring blizzards and low temperatures. The male penguins keep their eggs warm by balancing them on their feet for up to nine weeks, while the female goes fishing at sea. During this fasting period, these super-dads huddle in groups of up to 5,000 penguins to keep warm, losing 45 per cent of their body weight.

During the summer, around 4,400 scientists and support staff live on Antarctica, carrying out experiments. Some are drilling and extracting cylinders of ice more than three kilometres (two miles) long, to provide a record of climate covering perhaps the last 740,000 years. The ice contains ancient air bubbles and compressed layers of snow. Scientists are also drilling into underground lakes like Lake Vostok, which may contain water and microbes isolated from the outside world for a million years.

Astrophysicists also benefit from Antarctica's clean, dry air. IceCube is an experiment to track neutrinos created by exploding stars, as these ghostly particles pass through the Earth. Another experiment is attempting to detect faint light from the Big Bang that created our universe. Scientists are also studying the feeding habits of adélie penguins, using scales to weigh them on their favourite walking routes.

GLACIER POWER

Discover the awesome Earth-shaping power of gigantic rivers of ice

Glaciers are huge rivers or sheets of ice, which have sculpted mountain ranges and carved iconic peaks such as the pyramid-shaped Matterhorn in the Swiss Alps. The secret of this awesome landscape-shaping power is erosion, the process of wearing away and transporting solid rock. Glacial erosion involves two main mechanisms: abrasion and plucking. As glaciers flow downhill, they use debris that's frozen into the ice to 'sandpaper' exposed rock, wearing them away and leaving grooves called 'striations'. This is the process of abrasion. Plucking, however, is where glaciers freeze all around rock and tear away loose fragments of it as they pull away.

Today glaciers are confined to high altitudes and latitudes, where the climate is cold enough for ice to persist all year round. During the ice ages, however, glaciers advanced into valleys that are now free of ice. Britain, for example, was completely covered by ice as far south as the Bristol Channel.

You can spot landforms created by ancient ice. Cirques are armchair-shaped hollows on mountainsides, which often contain lakes called 'tarns'. They're also the birthplaces of ancient glaciers. During cold periods, ice accumulated in shady rock hollows, deepening them to form cirques. Then, when the ice melted, it left a depression in the mountainside, which water would fill up. When two cirques formed back-to-back, they left a knife-edge ridge called an 'arête'. Pyramidal peaks were created when three or more cirques formed. Eventually the cirque glacier spilled from the hollow and flowed downhill as a valley glacier. This glacier eroded the valley into a U-shape, with steep cliffs called 'truncated spurs'. When the glacier melted, tributary valleys were left hanging high above the main valley floor.

Hard rock outcrops in the valley were smoothed into mounds orientated in the direction of ice movement. Rock drumlins are shaped like whalebacks, adopting a smooth, convex shape. Roche moutonnée have a smooth upstream side, and a jagged downstream side formed by plucking. Where valley rocks varied in strength, the ice cut hollows into the softer rock, which filled with so-called 'paternoster' lakes.

LEFT
Perito Moreno Glacier, Argentina, is about 30 kilometres (19 miles) long

ICEBERGS

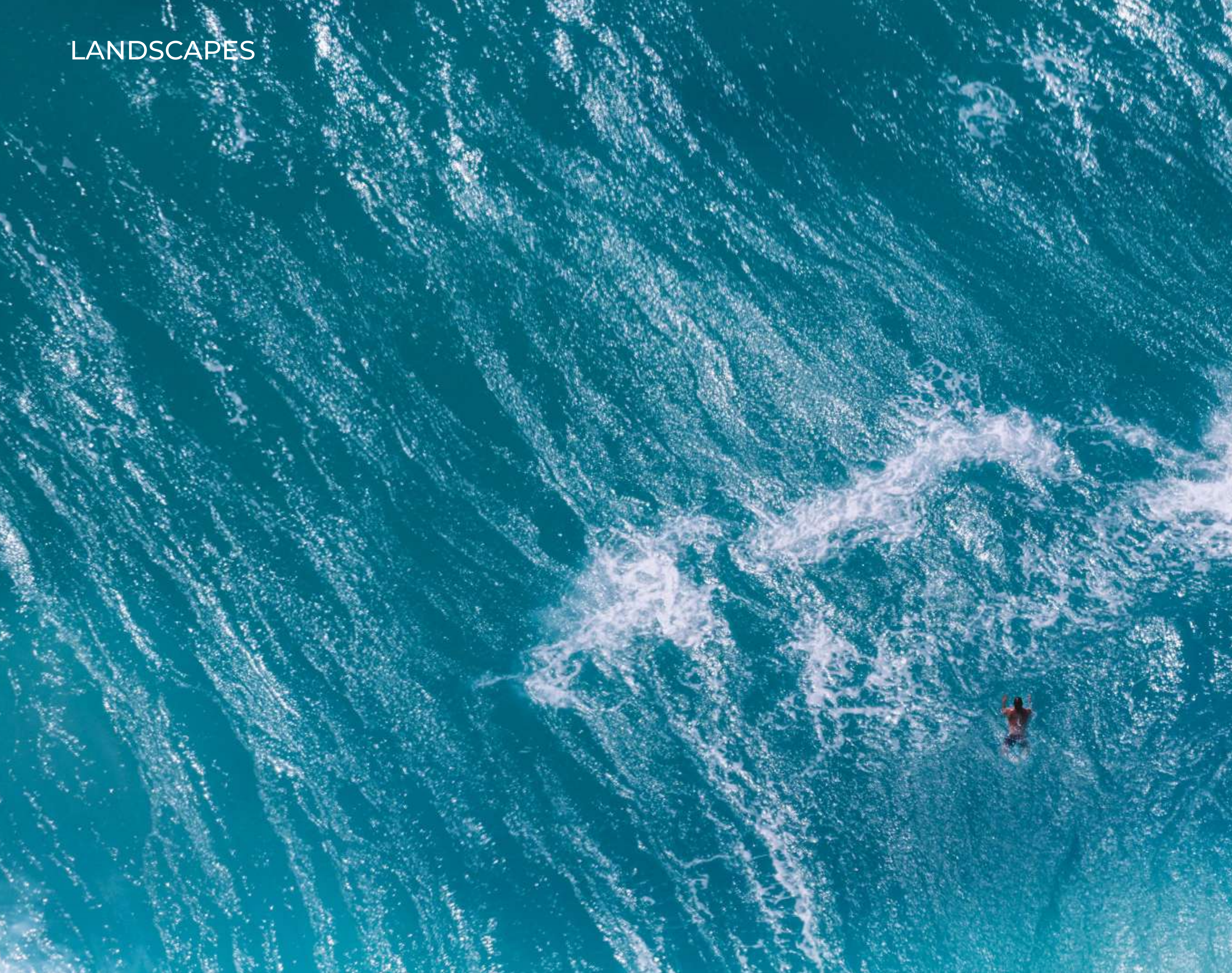
How were these ominous obstacles formed?

An iceberg only becomes an iceberg once it has broken away from the front of a glacier. When glacial ice arrives at the coast, it carries on moving out over the water and becomes an ice shelf. The movement of the tides, together with the sheer weight of the ice shelf, causes fissures that weaken the ice, causing bits to break off and float away. This 'breaking off' is called calving and the 'bits' are known as icebergs.

You only see a fraction of the iceberg above sea level, but it doesn't sink thanks to buoyancy. The upward force of buoyancy acting upon an object floating in a liquid is equal to the weight of the volume of liquid that is displaced by the object. Unlike other solids, ice is less dense than the liquid form it once had. When water is frozen it crystalises, meaning there's air between the molecules, reducing its density and enabling it to float.

Icebergs might look still, but they actually move very slowly across the sea

© Getty



AMAZING OCEANS

Take the plunge into our planet's most diverse ecosystem and discover its greatest secrets

Many are aware of the oceans' vital statistics: over 70 per cent of our planet is covered in water, and over 95 per cent of the water on Earth is contained within the oceans. These vast bodies of water sustain life, from the highest, most terrifying shark to the smallest piece of plankton, as it cycles through our ecosystems and atmosphere. The ocean seems invincible, but just how did it all get there?

There are a few theories about how the water on Earth came to be, including many different influencing factors. The first is the inside-out model, suggesting that once the Earth formed water existed in a bond with other minerals, then came to the surface as a result of volcanic activity. Another idea is that water was present as vapour, which condensed as Earth cooled. A third theory is the outside-in approach, stating that some of our water came from outer space as ice >

"WITH TECHNOLOGY THESE DAYS, IT'S IMPOSSIBLE NOT TO WONDER WHAT ELSE IS OUT THERE"

contained within asteroids or comets. Regardless of which is true, the first permanent ocean on Earth is thought to have formed between 4.3 and 3.8 billion years ago.

The metamorphosis into the map we know today is the result of tectonic activity. Earth's crust floats on a layer of molten rock, known as the mantle. The crust is separated into several plates that, thanks to convection currents, are constantly moving against each another, spreading apart or disappearing underneath one another. At areas where the plates are pulling away, magma from beneath the crust wells up in the gap created by the separating plates. This cools, hardens and creates new layers of rock, which is how some oceans are growing at a surprisingly fast rate – sometimes more than 15 centimetres (5.9 inches) per year.

The water bodies of our five main oceans are all interlinked, cycling through a series of currents. There are two types: surface and deep-water currents. Surface currents are whipped up by wind and governed by landforms and the Coriolis effect – a force that exists because of the Earth's spin on its axis. This force also has an effect on the water bodies within oceans and produces large-scale whirls of water that circulate around major ocean basins, known as gyres.

The deep-water variety of currents, meanwhile, is mainly a result of water temperature and salinity at the depths of ocean basins, known as thermohaline circulation. Salty, chilly water from the poles is dense, so it sinks to the bottom and slips along the seafloor. Water from the North Pole flows south, through the Atlantic down to the Southern Ocean. It then heads into the Indian and Pacific Oceans, where it heats up as it encounters warmer waters. Heated water that is less salty is less dense, so it rises but sinks again once it eventually reaches the poles and cools. It's estimated that it takes 1,000 years for water to complete this global ocean conveyor belt.

The circulation of water transports oxygen and nutrients around the oceans. It also carries vast amounts of moisture and heat around our planet, which affects our climate. Without the currents to regulate the uneven distribution of solar radiation that reaches Earth's surface, the climate would be far more extreme.

One major climactic process produced by ocean current activity is El Niño – the appearance of warm surface water off the coast of Peru every few years in December. This warming process is actually a by-product of a much larger ocean process known as the El Niño Southern Oscillation (ENSO), which is a natural climate phenomenon concerning oceans and atmospheres, the effects of which can have widespread implications for global weather.

The Sun-lit surface of the oceans is known as the epipelagic zone, whereas on land photosynthesis forms the basis of the food chain. Plankton blooms take advantage of >

ABOVE
No one knows how many species of marine life are yet to be discovered

LEFT
The big blue can be beautiful and useful – but it can also be dangerous

the light and provide the dinner of choice for many marine species. The smaller fish provide food for larger hunters and so the transfer of energy is passed down the oceans' layers.

In the mesopelagic zone, light gradually tails off to twilight and photosynthesis is no longer possible. Beneath this is the blackness of the bathypelagic zone, some 1,000 metres (3,300 feet) below the surface. Finally, deeper still, the crushing depths of the abyssopelagic zone are found at the very bottom of the ocean basins.

The waters of ocean trenches are known as the hadalpelagic zone – an unforgiving realm of inky darkness, freezing waters and crippling pressure, yet a surprising array of life survives there against the odds. At the deepest point – the Challenger Deep in the Mariana Trench – the pressure is more than 1.2 tons per square centimetre (7.7 tons per square inch), which is the equivalent of one person trying to hold up 50 jumbo jets!

Due to tectonic activity, ocean trenches and areas around them are punctuated with large vent chimneys that spew out chemical-rich water from within Earth's core. Vent communities are teeming with unique species, thanks to the presence of bacteria that use chemosynthesis to form the basis of the food chain. The bacteria use hydrogen sulphide in the vent water, along with oxygen and carbon dioxide, to create sugars, providing sustenance for smaller vent-dwellers. This gets transferred up the food web and soon the vent is jumping with biodiversity.

It's said we know more about outer space than we do about our oceans on Earth. It's not hard to see why, when the average depth of the oceans is more than 3.7 kilometres (2.3 miles). As well as sending ROVs (remotely operated vehicles) and subs down to investigate the depths, oceanographers have developed many different methods for sampling this watery world.

For instance, the seafloor can be mapped using sound waves, which travel at 1,500 metres (4,921 feet) per second in water. Echo sounders, backscatter and sound velocity profilers can all be used to accurately detect the depth, shape and composition of the seabed.

Other methods for sampling the ocean include salinity and temperature profiling, while lowering instruments to depths and then returning them to the surface can build up a more detailed picture. Samples can also be taken using dredges, core samples and trawls to collect organic matter.

Satellites in orbit are equipped with various sensors to relay many different ocean variables back to Earth for analysis. For example, sea surface temperature, air-sea interactions, ocean waves, currents and sea-ice patterns can all be viewed and monitored from afar. There are also monitoring systems that use buoys moored in the seas that constantly measure ocean movements. This kind of technology is especially useful for applications such as advance warnings for tsunamis.

There's so much left to discover about our oceans and with so much technology at our fingertips, it's impossible not to wonder at what else could be out there. Exactly how many more breakthroughs are lurking just beneath the waves, waiting to be found?

RIGHT
The Salt Ponds of San Francisco change colour depending on the salinity

BELOW
The Great Blue Hole in Belize is over 300 metres wide and 152 metres deep

© Getty

BLUE HOLES

Stare into the dark abyss and explore the creation of mysterious underwater sinkholes

The most abundant examples of these striking geological phenomena are found in and around the islands of the Bahamas. Some 300,000 years ago, when the ice age caused the ice caps to grow and the sea level to fall by up to 120 metres (394 feet), conditions in the Bahamas were well-suited to the formation of underwater caves known as blue holes. A type of karst formation, the blue hole forms as a result of recently exposed soluble rock – such as the limestone uncovered due to a drop in sea level – being eroded by acidic groundwater and rain, which enters through open faults. This causes cavities, caverns and networks of underground tunnels that weaken the structure of the limestone until it collapses in on itself as a sinkhole. When the sea level rises again the entrance to the cave below the surface of the ocean becomes apparent due to the contrast of the deep dark blue of the sinkhole with the lighter shallows of the tropical oceans surrounding it.

One of the most remarkable examples of a blue hole on Earth is the practically perfect circle of the Great Blue Hole off the coast of Belize; at over 300 metres (1,000 feet) across it's also the world's largest. Underwater sinkholes can be as deep as several hundred metres and, due to their hostile conditions, pose an extremely dangerous challenge to even the most experienced divers.

A scuba diver explores a blue hole in Micronesia

©Science Photo Library

RED TIDES

Why crimson seas are not as unbelievable a sight as you might first think

A red tide is the rapid accumulation of a mass of aquatic algae made up of mobile single-celled micro-organisms called dinoflagellates – which means 'whirling whip' due to the nature of the tail-like projections that propel them through the water. The algae grows, or blooms, more rapidly than usual in order to consume nutrients that have suddenly risen up from the colder depths of the ocean below. The red hue is down to the presence of a certain species of dinoflagellate, or phytoplankton.

Together with the more abundant diatom algae, dinoflagellates make up the majority of ocean plankton. Despite the rather startling appearance of a sea turned red, many algal blooms are actually harmless. However, you shouldn't consume seafood following a red tide as certain phytoplankton can release harmful substances into the water. Some dinoflagellates can produce toxins when eaten by other creatures and the harmful substances then concentrate inside the creatures that feed on them, and subsequently any humans who go on to dine on the contaminated seafood.

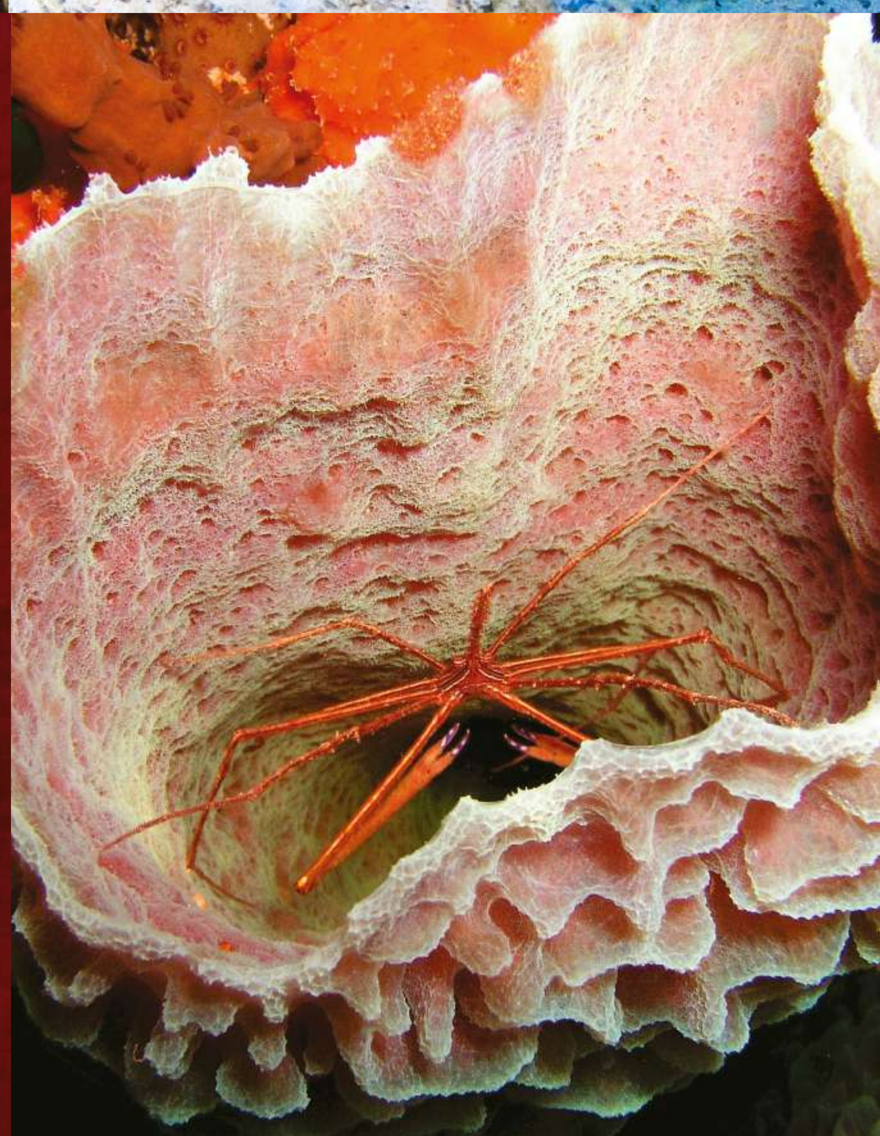
The billions of microscopic dinoflagellates in a red tide can also cause spectacular bioluminescence at night. One species in particular – the lingulodinium polyedrum – can create its own light from within. When the organism is jostled or collides with something in the ocean, a chemical reaction occurs when an enzyme called luciferase and a substrate called luciferin, both contained within the organism, combine. This is the catalyst for a chemical reaction that releases a flash of blue light. When this occurs millions of times simultaneously, the effect is remarkable.

ABOVE
An algal bloom on Canada's west coast turns the water orange

"DESPITE THE STARTLING APPEARANCE OF A SEA TURNED RED, MANY ALGAL BLOOMS ARE ACTUALLY HARMLESS"

CORAL REEFS

Recent research has resulted in surprising discoveries in the study of coral, including new reefs



A coral polyp on its own can measure just a few millimetres in size, but when it joins with others to form a colony, and the colony joins with other species to make a reef, those tiny polyps create one of the largest structures on Earth. It's thought that coral reefs contain 25 per cent of our planet's biodiversity, but cover just 0.2 per cent of its surface!

There are two types: hard and soft. The hard corals are the reef architects – they secrete a hard, slow-growing skeleton of calcium carbonate that fuses together over time to create the giant, natural barriers. Soft corals secrete skeletons that aren't as tough, but they still play an important part in reef growth and health.

The corals that grow in the shallows need super clear water, as light is essential for their growth. Their tissues contain tiny algal cells called zooxanthellae that photosynthesise and provide the coral with food. The algae also gives the coral its tropical, vibrant hue, turning the reef into a beautiful riot of submarine colour.

Deep-water corals don't rely on symbiotic algae for food because they live in the dark, so instead they catch their own. Corals have a surprising method of predation. Each individual polyp in a colony has stinging cells called nematocysts that are triggered by touch. Depending on the species, the nematocysts can deliver a powerful and sometimes lethal toxin, allowing the coral to take down prey.

With everything in delicate balance, coral reefs that live near land often rely on other interlinked ecosystems nearby to thrive. Mangroves are important, as these salt-water trees trap sediment and run-off from the land, filtering pollution and providing nutrients. Their long, submerged roots are also important nursery grounds for species that then make their way to the reef as adults.

"THE ALGAE GIVES THE CORAL ITS TROPICAL, VIBRANT HUE"

Similarly, seagrass meadows often grow between mangroves and reefs, providing essential food for grazers and stabilising the seabed, keeping the water clean. Research has also shown that coral reefs that grow in conjunction with mangroves may not be as susceptible to bleaching.

Coral bleaching events happen when the corals undergo thermal stress. To thrive, most tropical coral species need a water temperature of 18-29 degrees Celsius; they are highly sensitive to temperature fluctuation. If water temperatures get too high, the corals react by expelling their symbiotic zooxanthellae. This turns them a bright white colour, which can eventually lead to their death.

2016 saw one of the worst ever coral bleaching events. As sea surface temperatures have risen by one degree Celsius over the last century, corals have been pushed to the brink. Some 67 per cent of corals were affected in the worst-hit areas of the Great Barrier Reef and some publications even published obituaries for the marine site. But luckily, for now, the Great Barrier Reef still prevails.

ABOVE
The Great Barrier Reef is home to around 1,500 species of fish

TOP LEFT CLOCKWISE
Reef sharks are one of the major predators living in the waters

Green turtles travel between the land they hatched on and the sea

Arrow crabs are found on several coral reefs such as in the Caribbean

Clownfish nests have sea anemone that sting other fish who try to enter

There are some coral types that have already adapted to temperature extremes – the corals of Kimberley in western Australia make up one such reef. The area has the largest tropical tides in the world (up to ten metres) and the corals are repeatedly exposed to the air and soaring midday temperatures, as well as super-heated stagnant tidal pools. These conditions would be deadly to coral species living elsewhere, but the Kimberley corals flourish! Interestingly, the corals exposed to these extremes showed a better resistance to hot water when tested, indicating that a highly variable environment may hint to bleaching resistance.

Another incredible adaptation of coral is the 'phoenix effect'. In 1998 a disastrous coral bleaching event killed off nearly 16 per cent of the world's corals. Divers in Rangiroa Lagoon in French Polynesia had noticed that the super-hardy porites corals had also succumbed to bleaching and projected that, based on growing rates, it would take the reef over 100 years to recover. However, 15 years later those same divers returned to find the reef back to the thriving oasis it had once been.

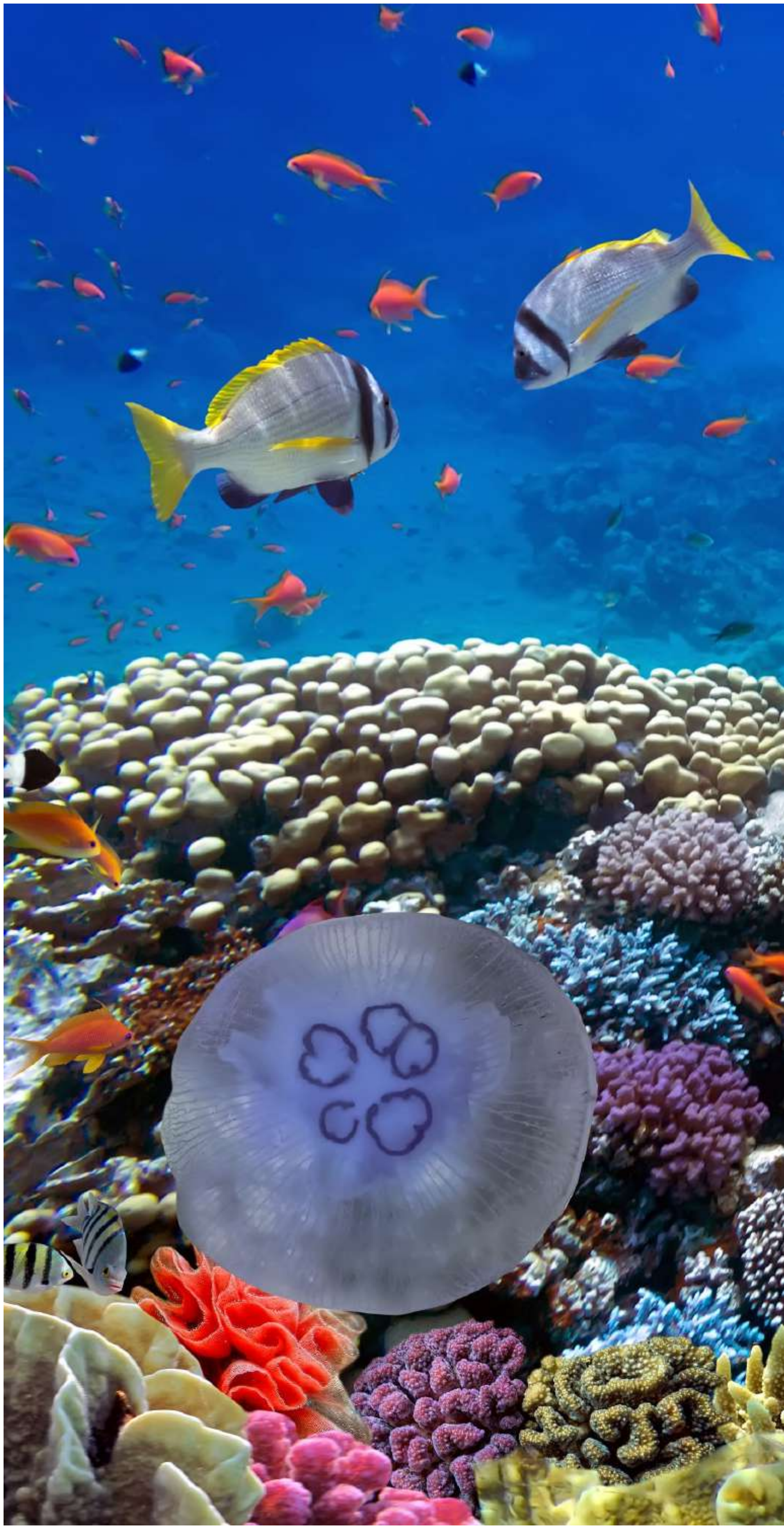
One theory about how the corals were able to recover so quickly is that perhaps the giant structures aren't as 'dead' as first thought. It's believed that if some of the colony tissue hidden deep within the skeleton was more protected, then it was able to recolonise across the original skeleton once temperatures improved.

Another astounding discovery from 2016 was the Amazon Reef, an extensive deep-water reef system of sponges, corals and rhodoliths living precisely where scientists never thought corals could – under the muddy sediment plume of the mouth of the Amazon River. 120 kilometres off the coasts of Brazil and French Guinea, between 50 and 100 metres below the water's surface, the reef sits unencumbered by the river outflow.

The topography of the seabed and the intensity of the currents mean that the slick of sediment-laden fresh water that spills from the Amazon doesn't reach deep enough to affect the corals, which need a saline environment to thrive. Despite having lower biodiversity than expected in an established warm-water reef, it is an incredible discovery.

New techniques in remote sensing are making it even easier to study coral reefs and get a clearer picture of how they work and the state of their health worldwide. We can view reefs from the air and from the sea with state-of-the-art equipment like ROVs. We can even analyse coral (live and fossilised) to learn more about Earth's prehistoric climate by analysing the chemical properties of their skeletons.

Coral reefs provide a habitat and food for fish that we eat, they protect our land from storms and erosion, they dissipate wave energy, and reefs also provide thousands of jobs for people worldwide. Despite coral being an incredibly hardy and resilient creature, it is still under threat from ocean acidification and warming temperatures. The loss of a reef can cause a catastrophic ecosystem shift where great swathes of ocean life suffer as a consequence. They are tough, but coral also need protection so that generations to come may enjoy the same reef benefits as we do today.



RIGHT
Turtles, snakes, jellyfish, crustaceans, mollusks and more all live in coral reefs

THE GRAND PRISMATIC SPRING

Be immersed in the heat and colour of this wonder

Yellowstone Park, Wyoming, became the world's first national park when President Ulysses S Grant signed it into law in 1872. It's not hard to see why the government wanted to preserve this area of great natural beauty, especially with features like this: the world's third-largest hot spring.

The Grand Prismatic Spring is Yellowstone's largest at 90 metres (295 feet) wide and 50 metres (164 feet) deep, and works like many of the park's hydrothermal features. Water deep beneath the ground is heated by magma and rises to the surface unhindered by mineral deposits. As it bubbles to the top it cools and then sinks, only to be replaced by hotter water coming from the depths in a continuous cycle. The hot water also dissolves some of the silica in the rhyolite rocks in the ground, creating a solution that's deposited as a whitish siliceous sinter onto the immediate land that is surrounding the hot spring.

So what makes all the pretty colours? That's not due to chemicals, anyway. The iridescent pigments are caused by bands of microbes – cyanobacteria – that thrive in these warm to hot waters. Moving from the coolest edge of the spring along the temperature gradient, the calothrix cyanobacteria lives in temperatures of no less than 30 degrees Celsius (86 degrees Fahrenheit), can live out of the water too and produces the brown pigment that frames the spring. Phormidium, meanwhile, prefers a 45-60-degree-Celsius (113-140-degree-Fahrenheit) range and creates the orange pigment, while synechococcus enjoys temperatures of up to 72 degrees Celsius (162 degrees Fahrenheit) and is yellow-green. The deep blue colour seen in the centre is the natural colour of the water and is too hot for most bacteria, although it's suspected that aquifex, a microbe that thrives in near-boiling water, lives off the hydrogen gas dissolved in the emerging Grand Prismatic Spring's waters.

NASA studies the hot spring as it may be similar to those on other planets

WEATHER

LIGHTNING

Capable of breaking down the resistance of air, lightning is a highly visible discharge of electricity capable of great levels of destruction

Lightning occurs when a region of cloud attains an excess electrical charge, either positive or negative, that is powerful enough to break down the resistance of the surrounding air. This process is typically initiated by a preliminary breakdown within the cloud between its high top region of positive charge, large central region of negative charge and its smaller lower region of positive charge.

The different charges in the cloud are caused when water droplets are supercooled within it to freezing temperatures and then collide with ice crystals. This process causes a slight positive charge to be transferred to the smaller ice crystal particles and a negative one to the larger ice-water mixture, with the former rising to the top on updrafts and the latter falling to the bottom under the effect of gravity. The consequence of this is gradual charge separation between the upper and lower parts of the cloud.

This polarisation of charges forms a channel of partially ionised air – ionised air is that in which neutral atoms and molecules are converted to electrically charged ones – through which an initial lightning stoke (referred to as a 'stepped leader') propagates down through towards the >

Lightning strikes during a storm over the town of Sedona in Arizona

“DUE TO THE MASSIVE POTENTIAL DIFFERENCE BETWEEN CHARGE AREAS THE RETURN STROKE CAN HOLD CURRENTS UP TO 30,000 AMPERES AND REACH 30,000 DEGREES CELSIUS”

ground. As the stepped leader reaches the Earth, an upwards connecting discharge of the opposing polarity meets it and completes the connection, generating a return stroke that due to the channel now being the path of least resistance, returns up through it to the cloud at one-third the speed of light and creating a large flash.

This leader-return stroke sequence down and up the ionised channel through air occurs three or four times per strike, faster than the human eye is capable of perceiving. Further, due to the massive potential difference between charge areas – often extending from ten to 100 million volts – the return stroke can hold currents up to 30,000 amperes and reach 30,000 degrees Celsius. Typically the leader stroke reaches ground in ten milliseconds and the return stroke reaches the instigating cloud in 100 microseconds.

Lightning, however, does not just occur between clouds (typically cumulonimbus or stratiform) and the ground, but also between separate clouds and even intra-cloud. In fact, 75 per cent of all lightning strikes worldwide are cloud-to-cloud or intra-cloud, with discharge channels forming between areas of positive and negative charges between and within them. In addition, much lightning occurs many miles above the Earth in its upper atmosphere (see ‘Atmospheric lightning’ boxout), ranging from types that emanate from the top of clouds, to those that span hundreds of miles in width.

Interestingly, despite the high frequency of lightning strikes and their large amount of contained energy, current efforts by the scientific community to harvest its power have been fruitless. This is mainly caused by the inability of modern technology to receive and store such a large quantity of energy in such a short period of time, as each strike discharges in mere milliseconds. Other issues preventing lightning’s use as an energy source include its sporadic nature – which while perfectly capable of striking the same place twice, rarely does – and the difficulties involved in converting high-voltage electrical power delivered by a strike into low-voltage power that can be stored and used commercially.

ABOVE
Cloud-to-cloud lightning streaks across the Masai Mara Game Reserve in Kenya, Africa

RIGHT
The saying that lightning never strikes the same place twice isn’t true

SUPERCELL THUNDERSTORMS

Why do those blinding flashes and ominous rumbles occur?

Thunderstorms are both spectacular and a bit scary, but what creates this awe-inspiring mix of rain, thunder and lightning? On warm days, hot air forms near the Earth's surface. As hot air is less dense than cold air, it rises, pushing through the colder air above it. Eventually it cools enough for the moisture contained inside the air to condense. As the moisture in the air turns to liquid, it forms ice crystals. These ice crystals are dense, so they become heavier than the updraft and begin to fall down through the cloud. As they descend towards Earth they thaw and become rain.

When the water particles move through the cloud, electrons are stripped from them. Positively charged particles sit at the top of the cloud and negatively charged particles remain at the bottom. This induces a positive charge on the Earth's surface below, so the clouds are desperate to hand over their spare electrons. Once the charge has built up, the electrons from the cloud power towards the ground, discharged as a spark of electricity that we see as a bolt of lightning. As lightning can travel at a breakneck 160,000 kilometres (100,000 miles) per hour, it creates a lot of heat. This causes the air around the lightning to expand quickly, creating the vibrations that we hear as thunder.

Supercell thunderstorms are formed when thunderstorms and high winds collide and combine, causing what is called a mesocyclone. This will often lead to a tornado forming, as the rapidly rotating wind combines with the updraft to create a weather system that pulls objects upward with tremendous force. High precipitation supercells are the worst kind of them all, as the tornado is hidden behind a wall of water, making it tricky to spot and avoid. On top of it all, the heavy rain makes flash floods a real risk.

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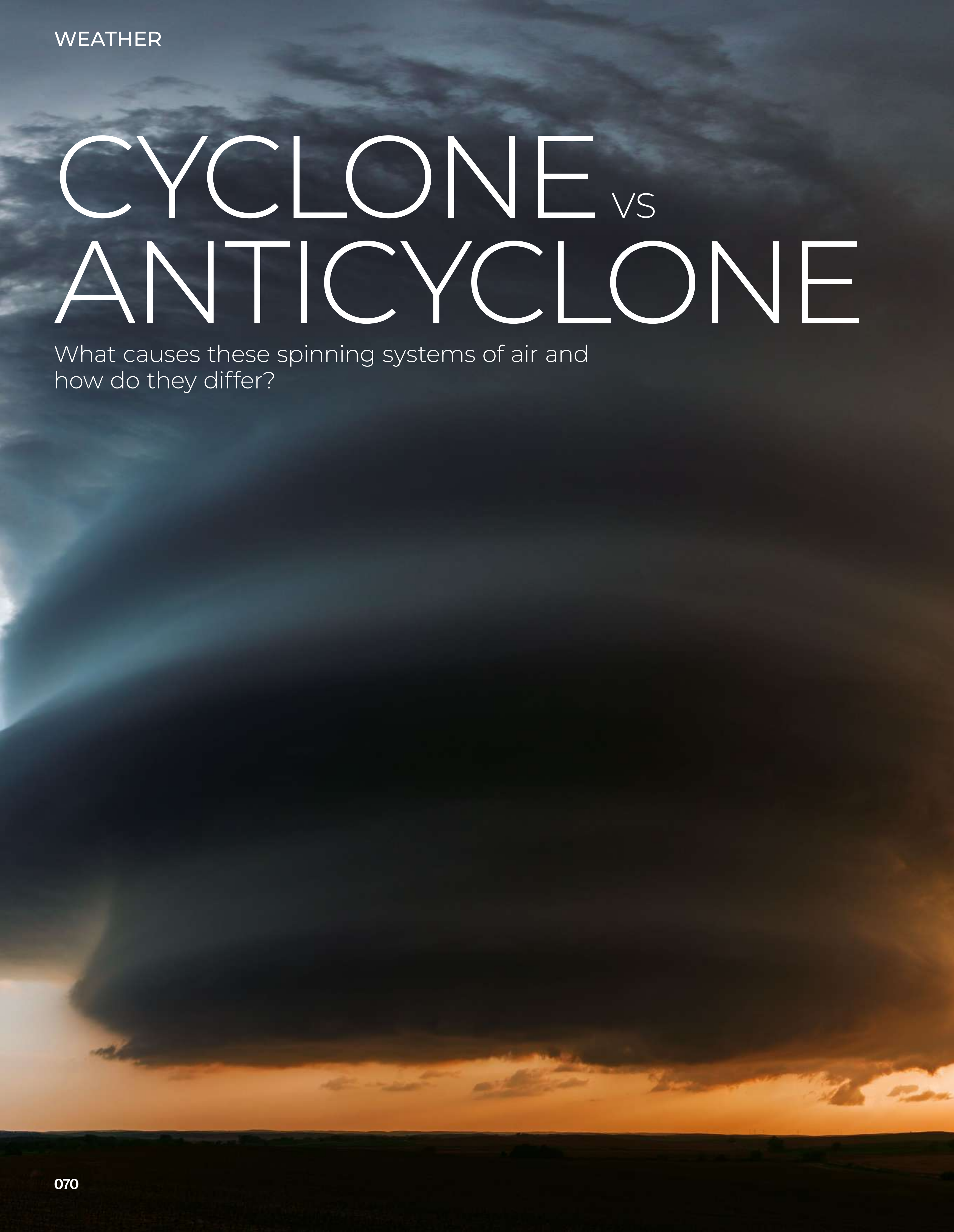
CYCLONE VS ANTICYCLONE

What causes these spinning systems of air and how do they differ?



"ANTICYCLONES ARE ASSOCIATED WITH SUMMER WEATHER AND DRY WINTER DAYS"

Cyclones and anticyclones are generated when areas of high and low air pressure collide. These are created by differences in temperature and humidity.

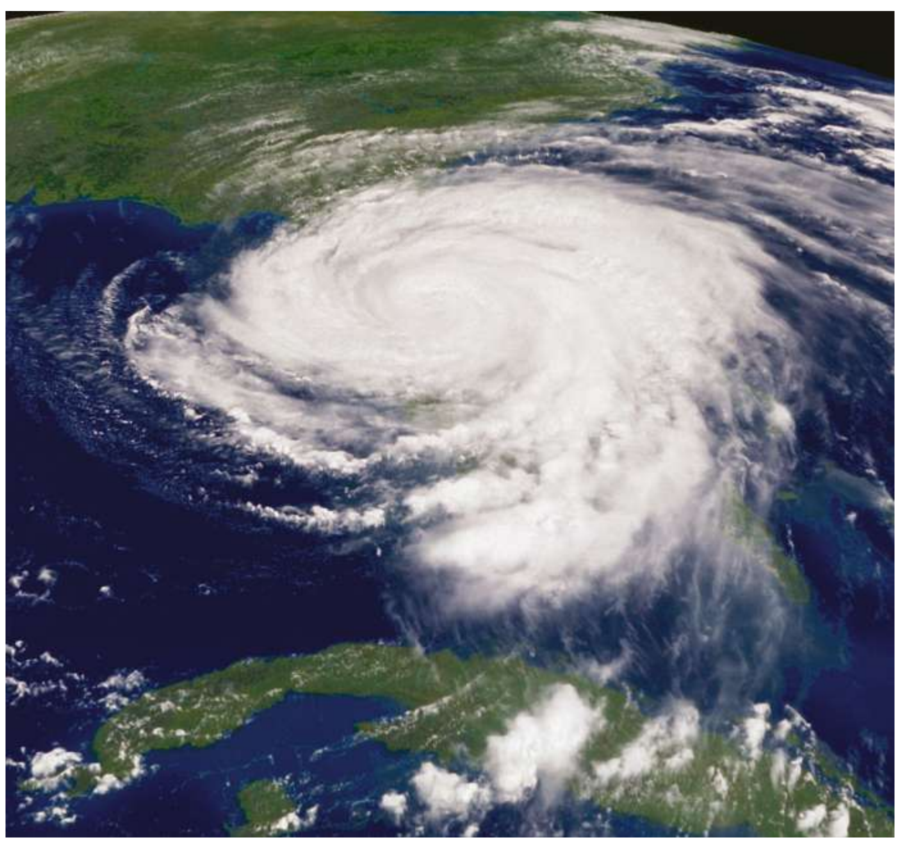
Air temperature affects the molecules' kinetic energy. The higher the temperature, the more the molecules move and collide. Humidity, on the other hand, affects the air itself. The atmosphere's main constituents – diatomic oxygen and nitrogen – are heavy compared to water vapour. The water in humid air replaces some of the heavier molecules, making it lighter than dry air, and therefore of a lower pressure.

An anticyclone is a region of high atmospheric pressure. The air descends through the system, spreading out sideways as it makes contact with the ground. The compressed air causes a rise in temperature – hence why anticyclones are associated with summer weather and dry winter days.

In contrast, a cyclone is centred around a region of low pressure. Inward spinning winds draw air upwards into the system – as it rises, water vapour cools and condenses, resulting in cloudy weather and storms.

LEFT
A Mesocyclone moves through Nebraska's Great Plains

BELOW
Anticyclones have periods of calm weather that can last a few days



TORNADOES

The science behind tornadoes with the power to devastate cities

Every year around 1,200 tornadoes touch down in the USA. Most occur in a region nicknamed Tornado Alley, with Texas, Oklahoma and Kansas at its core.

An incredibly destructive tornado was the Moore Tornado, which touched down at 2.56pm CDT on 20 May 2013, near Newcastle, Oklahoma. It was on the ground for 40 minutes and drew a 27-kilometre (17-mile) path through the state, 2.1 kilometres (1.3 miles) across at its widest point. Wind speeds were in excess of 322 kilometres (200 miles) per hour, placing the tornado in the highest category on the Enhanced Fujita (EF) Scale: EF5. Tornadoes of this class cause near-total devastation, completely levelling multistorey buildings, tearing homes from their very foundations and lifting asphalt from the roads.

North America has unique geography, which provides a deadly spawning ground for storms and tornadoes. The Rocky Mountains extend from north to south along the west side of the continent. As wind travels over the Rockies, it becomes cold and loses moisture via rain and snow, producing cool, dry air at high altitudes. When this air hits >

Some tornadoes have multiple vortices such as this one in Kansas

"IT STARTED OUT AS A WEAK EF0 TWISTER... BUT WITHIN TEN MINUTES IT HAD INTENSIFIED TO EF4"

warm, humid air from the Gulf of Mexico water vapour condenses and forms storm clouds. This releases huge amounts of energy, causing atmospheric instability.

On 20 May 2013, severe weather warnings were issued for Oklahoma; a polar jet stream came over the Rockies into the southern Great Plains, and simultaneously a low-pressure system moved over the Upper Midwest region. Differences in wind speed at different altitudes – known as wind shear – caused the air to spin, circulating in a horizontal vortex, and in combination with moisture and atmospheric instability. At 2pm CDT, this led to the development of a thunderstorm containing persistent, rotating mesocyclones.

Mesocyclones powerful enough to generate tornadoes often result in hailstorms. Updraughts of warm air carry water droplets high into the atmosphere, where they freeze before being carried downwards by cold downdraughts. If they become caught in an updraught again they will refreeze, adding a new layer of ice. This process can repeat several times, generating hailstones that are the size of golf balls or even larger. Oklahoma was harshly pelted with hail as the storm intensified.

If there is sufficient updraught to tighten the central vortex of a mesocyclone it begins to twist, resulting in a powerful vertical column. The inward and outward airflows cause a drop in pressure at the centre, and form what is known as a dynamic pipe. At the core of the vortex, the pressure is lowered, which sucks in more air, causing the column to lengthen and extend down towards the ground.

A tornado warning was issued in Oklahoma at 2.40pm, and the tornado that ravaged Moore touched down 16 minutes later. It started out as a weak EF0 twister, capable of only minor damage to roof shingles, trees and guttering, but within ten minutes it had intensified to EF4. EF4 tornadoes have extremely destructive winds of up to 322 kilometres (200 miles) per hour and, on its path to the city of Moore, it severely damaged a bridge and killed nearly 100 horses at the Orr Family Farm.

Once in the city, the storm intensified to EF5 – the highest rating for a tornado – and reduced many buildings to rubble. It lost its peak strength and returned to EF4 classification, but the intensity of the storm caused a great deal of damage: 13,500 homes were destroyed, or damaged, affecting 33,000 people, 24 people were killed and hundreds more injured.

The tornado thankfully continued to weaken until it eventually dissipated at 3.35pm, about eight kilometres (five miles) east of Moore.

RIGHT
Tornados can vary in shape, especially as they start to dissipate

ABOVE
The utterly devastating aftermath of a tsunami in Sumatra, Indonesia

RIGHT
The 2004 tsunami striking the coast of Thailand

TSUNAMIS

Among the most epically destructive forces on Earth, tsunamis cause catastrophic levels of carnage, unearthing trees, levelling buildings and ending life

Tsunamis form through a complex, multi-stage process that emanates from the massive energy release of a submarine earthquake, underwater or coastal landslide, or volcanic eruption.

The first stage in this formation begins when the tectonic upthrust caused by the quake or impulse event causes massive amounts of ocean water to be displaced almost instantaneously. This action kick-starts a simple series of progressive and oscillatory waves that travel out from the event's epicentre in ever-widening circles throughout the deep ocean. Due to severe levels of energy propagated from the impulse, the waves build in speed very quickly, reaching up to an incredible 500mph. However, due to the depth of water, the speed of the waves is not visible as they expand to have incredibly long wavelengths that can stretch between 60-120 miles. Because of this, the wave amplitudes (the wave height) are also very small as the wave is extremely spread out, only typically measuring 30-60 centimetres. These long periods between wave crests – coupled with their very low amplitude – also mean that they are particularly difficult to detect when out at sea.

Once generated, the tsunami's waves then continue to build in speed and force before finally approaching a landmass. Here the depth of the ocean slowly begins to reduce as the land begins to slope up towards the coastline. This sloping of the seabed acts as a braking mechanism for the high-velocity tsunami waves, reducing their speed through colossal friction between the water and the rising earth. This dramatic reduction in speed – which typically takes the velocity of the tsunami to one-tenth of its original speed – also has the effect of reducing the length of its waves, bunching them up and increasing their amplitude significantly. Indeed, at this point coastal waters can be forced to raise as much as 30 metres above normal sea level in little over ten minutes.

Following this rise in sea level above the continental shelf (a shallow submarine terrace of continental crust that forms at the edge of a continental landmass) the oscillatory motions carried by the tsunami are transferred into its waters, being compressed in the process. These oscillations under the pressure of the approaching water are then forced forwards towards the coast, causing a series of low level but incredibly fast run-ups of sea water, capable of propelling and dragging cars, trees, buildings and people over great distances. In fact, these run-ups are often responsible for a large proportion of the tsunami's damage, not the giant following waves. Regardless, however, following the run-ups the tsunami's high-amplitude waves continue to slow and bunch into fewer and fewer megawaves before breaking at heights between five and ten metres over the immediate coastline, causing great damage and finally releasing its stored energy.

Due to the severe hazards that tsunamis pose, research into their causes and tracking of their formation has increased through the 20th and 21st centuries. Currently, the world's oceans are monitored by various tsunami detection and prevention centres, such as the NOAA (National Oceanic and Atmospheric Administration) run Pacific Tsunami Warning Center (PTWC) based in Honolulu, Hawaii.

Set up back in 1949, the PTWC utilises a series of tsunami monitoring systems that delivers seismic and oceanographic data to it on a daily basis, with information transferred to it and other stations by satellite connection. This is one of two American-run centres that monitors the Pacific Ocean and it is responsible for detecting and predicting the size and target of any approaching tsunamis.

Tsunami prevention has also seen advances as construction techniques and materials have developed over the past century. Now areas that are prone to tsunamis, such as Japan's west coast, are fitted with large-scale sea walls, artificial deep-sea barriers, emergency raised evacuation platforms and integrated electronic warning signs and klaxons in coastal resorts and ports.

Areas that have been affected by tsunamis in the past are also fitted with physical warning signs and have specific evacuation routes that best allow for large numbers of people to quickly move inland. Unfortunately, however, despite many advances being made to ensure prone areas are protected and warned in advance, due to the transcontinental nature of generated tsunamis, remote or under-developed areas are still affected regularly, the consequences of which have been recently shown in the disastrous 2004 tsunami in the Indian Ocean that claimed over 200,000 lives.

"DUE TO SEVERE LEVELS OF ENERGY PROPAGATED FROM THE IMPULSE, THE WAVES BUILD IN SPEED VERY QUICKLY"

FOGBOWS

Is a fogbow really very different to a rainbow? And how exactly is it formed?

A fogbow is similar to a rainbow by being created from the same process of sunlight refraction and reflection.

However, rather than being formed by raindrops, a fogbow is formed by the water droplets found in fog, mist or cloud. Although sunlight enters, and reflects from, the droplets, forming a large circle opposite the Sun – just as it does when a rainbow is formed – fog droplets are much smaller than raindrops, causing the light to diffract. The diffraction process dominates the reflection process, resulting in a colourless phenomenon. Although colour is present, the bow in each colour is so broad that the colours overlap, resulting in this washed-out effect.

A fogbow appears in the Tetons of Wyoming in the United States

DROUGHT

The slightest shift in wind patterns can have terrible consequences

For areas that rely on regular rainfall to nourish vegetation, animals and a large human population, drought can be devastating, but in other parts of the world, hot, dry weather is a normal everyday occurrence. These arid climate conditions are caused by circulatory patterns of air in the Earth's atmosphere, known as Hadley cells.

In this weather system, intense exposure to sunlight at the equator causes warm, moist air to rise. As the air rises, it cools again, forming a low-pressure system that results in regular thunderstorms across the region. Above these storms, the jet stream – a current that flows through Earth's upper atmosphere – carries the air towards higher latitudes until it eventually descends over the tropics north and south of the equator. As it falls, it creates a high-pressure system that is responsible for the arid conditions of the Sahara and other deserts that populate this region.

Slight changes in this movement of air can result in unusual – and sometimes catastrophic – weather activity, such as flooding and drought. For example, if the air that normally descends over the tropics in the Northern Hemisphere is carried further north by the jet stream, it can bring extended periods of high pressure to Europe. This can cause precipitation levels to fall below the expected average for the region, resulting in a period of non-seasonal drought.

Despite using advanced weather prediction models, experts are still only able to forecast drought when it is less than a month away, making it very difficult for countries to prepare.

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AURORAS

Witness nature's amazing light show

Undoubtedly one of Earth's most amazing natural wonders, the polar auroras – otherwise known as the northern and southern lights – are a naturally occurring light display that takes place in the high latitude regions of the poles. They are characterised by diffuse coloured streaks through the night sky, winding and twisting like a liquid stream made of light.

Far from anything supernatural, auroras like this are actually the result of the collision of energetic charged particles with atoms in Earth's thermosphere, the highest layer of the atmosphere. These charged particles originate in the Earth's magnetosphere where solar winds from the Sun bombard the thermosphere, triggering the spectacular auroral mechanism.

The light results from the charged particles colliding with and ionising nitrogen atoms – that is the nitrogen atoms gain an electron – as well as oxygen and nitrogen atoms returning from an excited to a ground state, thereby forcing the emission of photons (quanta of light). The path and structure of the emitted photons are determined by the direction of the Earth's magnetic field lines, with the charged particles funnelled down and accelerated along them, hence the location of auroras around the north and south poles.

Interestingly, it's possible to determine the type of emissions reacting in the sky by studying the colour of an aurora, with oxygen emissions generating a green or brownish-hued illumination, while nitrogen emissions produce a blue or red display.

ABOVE
The lights are visible in many countries, including Iceland and Norway

RIGHT
Auroras can last from minutes to hours depending on conditions

"SOLAR WINDS FROM THE SUN BOMBARD THE THERMOSPHERE, TRIGGERING THE SPECTACULAR AURORAL MECHANISM"

© Getty

ROCKS, GEMS & FOSSILS

VOLCANOES

Around the world, sleeping giants lie in wait for their 15 megatons of fame

Imagine the Earth as a giant, ripe orange. Beneath the thin, dimpled peel is a thick layer of pulp and juice, 90 per cent of it liquid. The Earth's peel is called the lithosphere, a fragile crust of rock – 75-150 kilometres (45-95 miles) thick – that floats on a massive sea of impossibly hot, semi-fluid magma that extends 5,000 kilometres (3,100 miles) below the surface.

When German meteorologist Alfred Wegener first proposed his theory of 'continental drift' back in 1912, people thought he was crazy. How could a colossal hunk of solid rock such as Asia or Africa possibly drift? As we now know, the continents are indeed solid, but they are fragmented into seven major plates and seven minor plates that eternally jostle for position like buoys on troubled water.

The engines that power this perpetual tectonic dance are giant convection currents in the Earth's molten mantle that slowly push magma upward and outward. Wherever rising magma manages to break through the thin lithosphere, it's called volcanism, but the vast majority of volcanoes aren't the explosive, violent variety. Instead, they are slow-bubbling cauldrons along a 60,000-kilometre (37,000-mile) underwater seam called the mid-ocean ridge.

The mid-ocean ridge is like an open, oozing wound in the crust where two oceanic plates diverge. The plates are pulled away from each other by the slow and steady convection >

"90 PER CENT OF EARTHQUAKES OCCUR ALONG CONVERGENT PLATE BOUNDARIES AND SO DO THE WORLD'S BIGGEST AND DEADLIEST VOLCANOES"

ABOVE
In 1904, Mount Pelée erupted and it was one of the most deadly volcanoes

LEFT
There are two main varieties of lava: pahoehoe and a'a lava

currents and the gap between them is constantly refilled by thousands of unknown, unnamed underwater volcanoes. As this underwater lava cools, it creates new ocean floor covering 60 per cent of the Earth's surface.

Forget the orange analogy and think of the Earth's crust like a giant moving walkway in an airport. The walkway emerges from below the floor, travels a set distance and then rolls back underground. The divergent plate boundaries along the mid-ocean ridge are where the Earth's 'moving walkway' begins. The diverging plates are carried along this magma conveyor belt – travelling only three to four centimetres (one to 1.5 inches) per year – until they meet a plate moving in the other direction.

When two plates converge, something has to give. An incredible 90 per cent of earthquakes occur along convergent plate boundaries and so do the world's biggest and deadliest volcanoes. The prime example is the Ring of Fire, the unbroken string of seismic and volcanic activity that encircles the Pacific Ocean. The Ring of Fire is a giant subduction zone, where oceanic plates 'dive' below continental plates and are melted back into magma in the blazing hot forge of the mantle.

Ocean sediment holds tons of water, carbon dioxide, sodium and potassium. When oceanic crust enters the blast furnace of the mantle, these sea-borne elements lower the melting point of surrounding rock, forming a gaseous, yet viscous magma that rises quickly toward the surface. If the rising magma reaches an obstacle – an impenetrable thick layer of solid rock – it pools below the surface, building increased pressure as more gaseous, volatile molten materials push up from below. And then one day – boom! All it takes is a weak point in the cap of rock holding back the magma. On Mount St Helens, a landslide cleared a swath of rock from the north flank of the mountain, lowering the downward pressure on the boiling pot of magma below. The result was an explosion that produced a monstrous pyroclastic surge – a wall of searing hot fluidised gas, debris and ash – that vaporised everything within a 500-square-kilometre (193-square-mile) area.

Some of the most famous and infamous eruptions came from subduction zone volcanoes along the Ring of Fire: Tambora in Indonesia, Pinatubo in the Phillipines, Gagxanul in Guatemala, Mount Pelée in Martinique… the list of killer volcanoes goes on. In fact, 400 of the world's 500 known active volcanoes occur along subduction boundaries.

But not all famous volcanoes are of the subduction variety. The volcanoes of the Hawaiian Islands are an example of something called hot spot volcanism. Think back to those powerful convection currents in the mantle that push magma upward towards the crust. In certain 'hot spots' around the entire planet, convection currents are able to ooze magma to the surface with very little resistance.

Picture the hot spot under the Hawaiian Islands as a giant tube of toothpaste. Squeeze the tube and the little dollop of paste becomes the first Hawaiian Island, Kauai. Now keep the tube in the same place while the ocean plate travels a few

"WHEN A LAVA FLOW MEETS WATER, YOU GET LOVELY ROUNDED FORMATIONS"

hundred kilometres northwest. Squeeze the tube again and you've created the second island, Oahu. Hawaii, the Big Island, is still sitting over that magma pump, fuelling magnificent, slow-boiling eruptions that are literally building the island.

The intensity and duration of a volcanic eruption depends mostly on the consistency of the magma rising to the surface and the obstacles preventing the magma from reaching the surface. Subduction volcanoes are so ear-poppingly explosive because the magma fuelling them is loaded with gas bubbles and silica from sea floor sediments. The high silica content makes the magma more viscous, preventing gas bubbles from easily escaping. The result is like shaking a bottle of soda. When that pressure is released – pop!

The hot spot volcanoes of Hawaii, on the other hand, feature highly fluid magma formed from basaltic rock with low silica content. The 'watery' quality of Hawaiian magma allows gas to escape easily. After an initial, relatively calm eruption, Hawaiian volcanoes spew fountains of lava, forming large, river-like flows that creep slowly to the sea.

The Hawaiian volcanoes Mauna Loa, Kilauea and Mauna Kea are the most closely studied volcanoes in the world, which is why different varieties of lava are classified with Hawaiian names. Pahoehoe is a highly fluid basaltic lava that cools with a smooth, ropy surface. A'a is a thicker lava carrying large chunks of pyroclastic debris like lava blocks and bombs. The result is a slow, jagged flow that cools with a very rough-looking texture.

When a lava flow meets water, you get some lovely rounded formations called pillow lava, but if freshly emerging magma meets water, the results are far more explosive. A phreatic or 'steam blast' eruption discharges large rock fragments and ash, but little lava. The monstrous ash cloud that grounded flights across Europe for weeks was the product of magma meeting glacial ice. The ash from such an eruption isn't the soft, fluffy stuff that gets in your eyes when you have a campfire. Volcanic ash particles are extremely hard, jagged fragments of rock, minerals and glass that can be up to two millimetres (0.08 inches) in diameter.

The effect of a large-scale volcanic eruption is both local and global, immediate and long-term. Pyroclastic surges travelling 150 kilometres (93 miles) per hour can obliterate an entire city in a matter of seconds, while a massive ash storm can block the Sun's rays so thoroughly that the Earth's surface temperature lowers for months, if not years. The 1815 eruption of Tambora in Indonesia spewed so much ash into the global atmosphere that it created a 'year without a summer', complete with June snow storms in New York.

LEFT
The Mount St Helens eruption in 1980. The ash reached 24 kilometres (15 miles) high

THE GIANT'S CAUSEWAY

Discover the origins of this geological phenomenon, which consists of around 38,000 basaltic columns

On the north-east coast of County Antrimin, Northern Ireland, lies an unusual rock formation that draws in millions of visitors from around the world every year. They flock to see a vast plateau of polygonal basalt columns – commonly known as the Giant's Causeway – which looks like a carpet of enormous stepping stones extending out into the Irish Sea. The basalt pillars that make up this amazing rock formation dramatically range in size from a matter of centimetres to several metres high.

Although the Giant's Causeway is so-named due to an ancient legend, its formation actually began up to 65 million years ago during the Tertiary period when volcanic activity forced tectonic plates to stretch and break. This caused magma to spew up from inside the Earth and spill out across the surface as lava. The temperature of erupting lava can range from between 700 and 1,200 degrees Celsius (1,292 and 2,192 degrees Fahrenheit). However, upon contact with the surface it will immediately begin to cool. At first this cooling is extremely rapid and this results in a hardened crust forming on top of the superhot substance, which insulates the still liquid lava below. Because the lava is now insulated, the cooling becomes increasingly slow over time. While you could probably walk on the crust after just half an hour or so, thick lava flows can take many years to cool completely and solidify all the way through.

While the temperature falls, the lava dries out, and it's this drying that causes the solidifying lava to crack and form regular pillars of basalt rock. The size and shape of each column is determined by the rate at which the lava cools and dries, and therefore the speed at which what's called the 'drying front' moves. Scientists from the University of Toronto discovered that the slower the cooling rate, the larger the basalt columns that formed.

LEFT
The 38,000 stone columns vary in size from centimetres to metres

BELOW
Legend is that the causeway was used by giants walking to Scotland

Destruction in Kathmandu, Nepal, after the 2015 earthquake, which killed almost 9,000 people

EARTHQUAKES

What causes these devastating natural hazards, and how can we predict and prepare for them?

Earthquakes are one of our planet's most destructive natural forces, with the ability to flatten entire cities, trigger enormous tsunamis that wash away everything in their path, and cause a devastating loss of life.

Part of an earthquake's immense power lies in its unpredictability, as a huge quake can strike with very little warning and give those nearby no time to get to safety. Although we do not know when they will occur, we can predict where they are likely to happen, thanks to our knowledge of plate tectonics.

The thin top layer of the Earth, known as the crust, is divided into several plates that are all constantly moving. This is caused by immense heat from the core of the Earth creating convection currents in the fluid mantle just below the crust, which has the effect of shifting the plates in different directions.

>

"EARLY-WARNING SYSTEMS GIVE SECONDS OR MINUTES TO PREPARE BEFORE THE EARTHQUAKES HIT"

As the plates move, they collide, split apart or slide past each other along the plate boundaries, creating faults where the majority of earthquakes occur. At divergent or constructive plate boundaries, the plates are moving apart, causing normal faults that form rift valleys and ocean ridges. When plates move towards each other along convergent or destructive plate boundaries, they create a reverse or thrust fault, either colliding to form mountains or sliding below the other in a process known as subduction. The third type is a conservative or transform plate boundary, and involves the two parallel plates sliding past each other to create a strike-slip fault.

Being able to identify these fault lines tells us where earthquakes are most likely to occur, giving the nearby towns and cities the opportunity to prepare. Although the secondary effects of an earthquake, such as landslides and fires from burst gas lines, can be fatal, the main cause of death and destruction during earthquakes is usually the collapse of buildings. Therefore, particularly in developed parts of the world, structures near to fault lines are built or adapted to withstand violent shock waves. The surrounding population will usually carry out regular earthquake drills, such as The Great California ShakeOut, that gives people a chance to practise finding cover when a quake hits. Unfortunately, many poorer areas cannot afford to be so well prepared, and so when an earthquake strikes, the resulting destruction is often even more devastating and the death toll is usually much higher.

However, our knowledge of how earthquakes work and the development of new technologies are helping us to find potential methods for predicting when the next one will strike. Scientists can currently make general guesses about when an earthquake may occur by studying the history of seismic activity in the region and detecting where pressure is building along fault lines, but this only provides very vague results so far. The ultimate goal is to be able to reliably warn people of an imminent earthquake early enough for them to prepare and minimise the loss of life and property. Until then, being under the constant threat of an impending earthquake is unfortunately part of everyday life for those living along the Earth's constantly active fault lines.

FAR RIGHT
The 1960 Valdivia earthquake was the most powerful ever recorded

TOP RIGHT
Roads and bridges are often damaged or totally destroyed

BOTTOM RIGHT
Earthquakes can often lead to tsunamis, which cause more problems


PROSEM SA

FOSSILS

Obliterating the traditional perception of the origins and evolution of life on Earth, fossils grant us unique snapshots of what once lived on our ever-changing planet

The origin of life on Earth is irrevocably trapped in deep time. The epic, fluid and countless beginnings, evolutions and extinctions are immeasurable to humankind; our chronology is fractured, the picture is incomplete. For while the diversity of life on Earth today is awe-inspiring, with animals living within the most extreme environments imaginable – environments we as humans brave every day in an effort to chart and understand where life begins and ends – it is but only a fraction of the total life Earth has seen inhabit it over geological time.

Driven by the harsh realities of an ever-changing environment, Armageddon-level extinction events and the perpetual, ever-present force of natural selection, wondrous creatures with five eyes, fierce predators with 12-inch fangs and massive creatures twice the size of a double-decker bus have long since ceased to exist. They're forgotten, buried by not just millions, but billions of years. Still, all is not lost. By exploiting Earth's natural processes and modern technology over the last two hundred years, scientists and palaeontologists have begun to unravel Earth's tree of life and, through the discovery and excavation of fossils – preserved remains and traces of past life in Earth's crust – piece the jigsaw back together.

The fossilisation of an animal can occur in a variety of ways but, in general, it occurs when a recently deceased creature is rapidly buried by sediment or subsumed in an oxygen-deficient liquid. This has the effect of preserving parts of the creature – usually the harder, solid parts like its skeleton – often in the original, living form within the Earth's crust. The softer parts of fossilised creatures tend not to survive due to the speed of decay and their replacement by minerals contained in their sediment or liquid casing, a process that can leave casings and impressions of the animal that once lived, but not its remains. Importantly, however, creature fossilisation tends to be specific to the environmental conditions in which it lived – and these in themselves are indicative of certain time periods in Earth's geological history. For example, certain species of trilobite (an extinct marine arthropod) are only found in certain rock strata (layers of sedimentary and igneous rocks formed through mineral deposition over millions of years), which >

"EXCAVATING ANY DISCOVERED FOSSIL TO DATE AND ANALYSE IT IS A CHALLENGING, TIME-CONSUMING PROCESS"

itself is identifiable by its materials and mineralogic composition. This allows palaeontologists to extrapolate the environmental conditions (hot, cold, dry, wet and so on) that the animal lived and died in and, in partnership with radiometric dating, assign a date to the fossil and/or the period – helping us to build a better picture of these creatures that once roamed the planet we call home.

Interestingly, however, by studying the strata and the contained fossils over multiple layers, through a mixture of this form of palaeontology and phylogenetics (the study of evolutionary relatedness between organism groups), scientists can chart the evolution of animals over geological time scales. A good example of this process is the now known transition of certain species of dinosaur into birds. Here, by dating and analysing specimens such as archaeopteryx – a famous dinosaur/bird transition fossil – both by strata and by radiometric methods, as well as recording their molecular and morphological data, scientists can then chart its progress through strata layers to the present day. In addition, by following the fossil record in this way, palaeontologists can also attribute the geophysical/chemical changes to the rise, fall or transition of any one animal/plant group, reading the sediment's composition and structural data. For example, the Cretaceous-Tertiary extinction event is identified in sedimentary strata by a sharp decline in species' diversity – notably non-avian dinosaurs – and increased calcium deposits from dead plants and plankton.

Excavating any discovered fossil in order to date and analyse it is a challenging, time-consuming process, which requires special tools and equipment. These include picks and shovels, trowels, whisks, hammers, dental drills and even explosives. There is also an accepted academic method all professional palaeontologists follow when preparing, removing and transporting any discovered fossil. First, the fossil is partially freed from the sedimentary matrix it is encased in and labelled, photographed and reported. Next, the overlying rock (commonly referred to as the 'overburden') is removed using large tools up to a distance of five to eight centimetres (two to three inches) from the fossil, before it is once again photographed. Then, depending on the stability of the fossil, it is coated with a thin glue via brush or aerosol to strengthen its structure, before being wrapped in a series of paper, bubble wrap and Hessian cloth. Finally, it is transported to the laboratory.

ABOVE
Fossils like this nautilus shell can give an insight into prehistoric life

LEFT
Various dinosaur tracks from the early Jurassic period found in Arizona

THE WAVE

Check out this striking sedimentary rock formation in the USA

The Wave is a remarkable Jurassic Navajo Sandstone rock formation located within the hills of the Utah/Arizona border. The swirling, undulating rainbow of colour was formed from the iron-rich Arizona rocks throughout the last 200 million years. The sandstone in The Wave is a type of sedimentary rock, consisting of fine fragmented quartz particles that have been worn away and deposited on the riverbed.

As more and more layers of sedimentary particles were deposited, the sediment was compacted and bound together by minerals to form the fragile yet strikingly striated rocks that are common to the Coyote Buttes region of the Paria Canyon-Vermilion Cliffs Wilderness area in Arizona. The multicoloured layers of rock that make up The Wave are known as strata and they were created due to the presence of different rock and sediment types featuring various thicknesses and hardness. While usually the sediment layers form horizontally one on top of the other, contortion of the Earth's crust can cause the rock to twist, fold and buckle into different directions.

The soft, brittle rocks of The Wave are so delicate that the Bureau of Land Management has imposed a limit of just 20 hikers per day who are allowed to venture into the North Coyote Buttes area.

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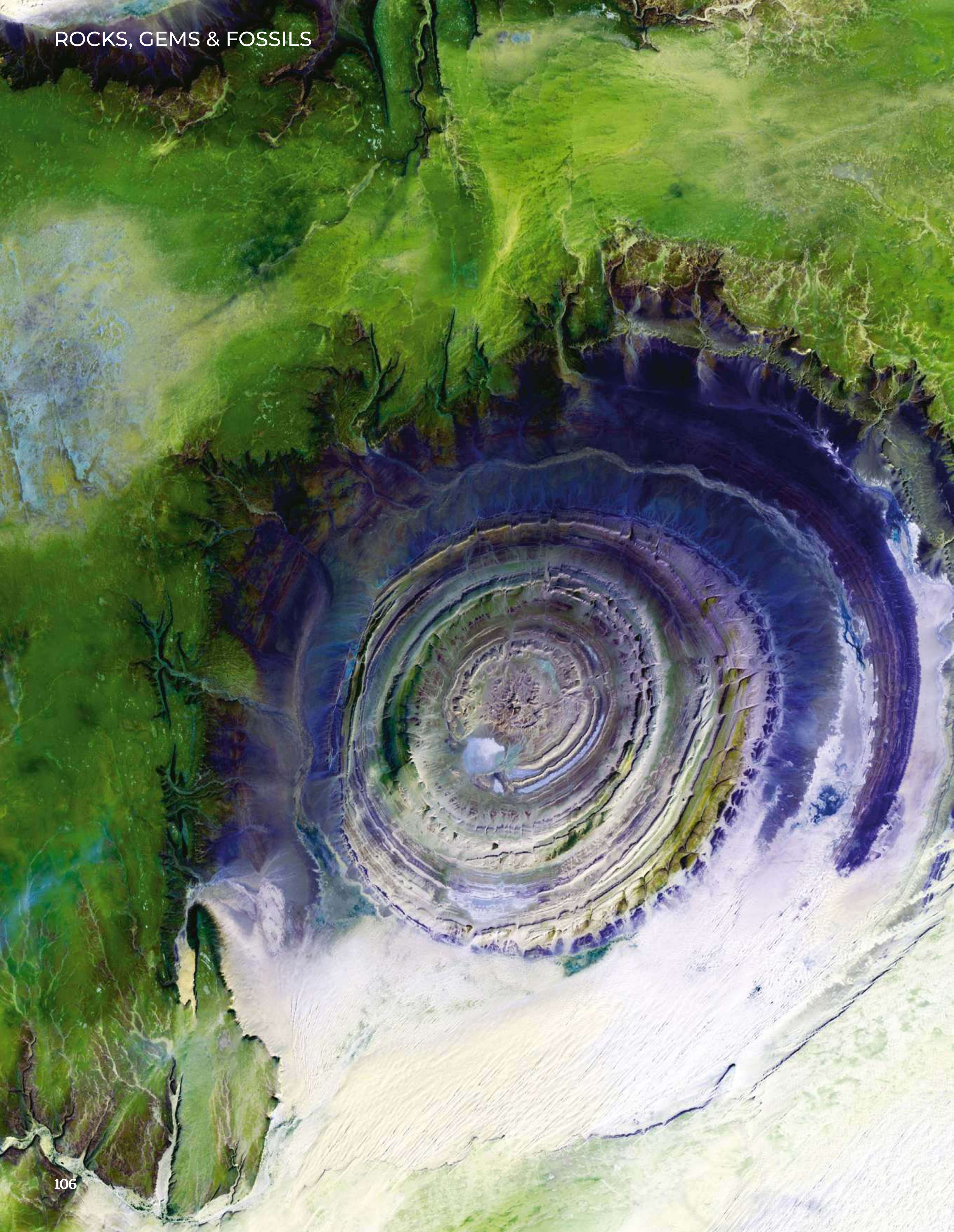


THE EYE OF THE SAHARA

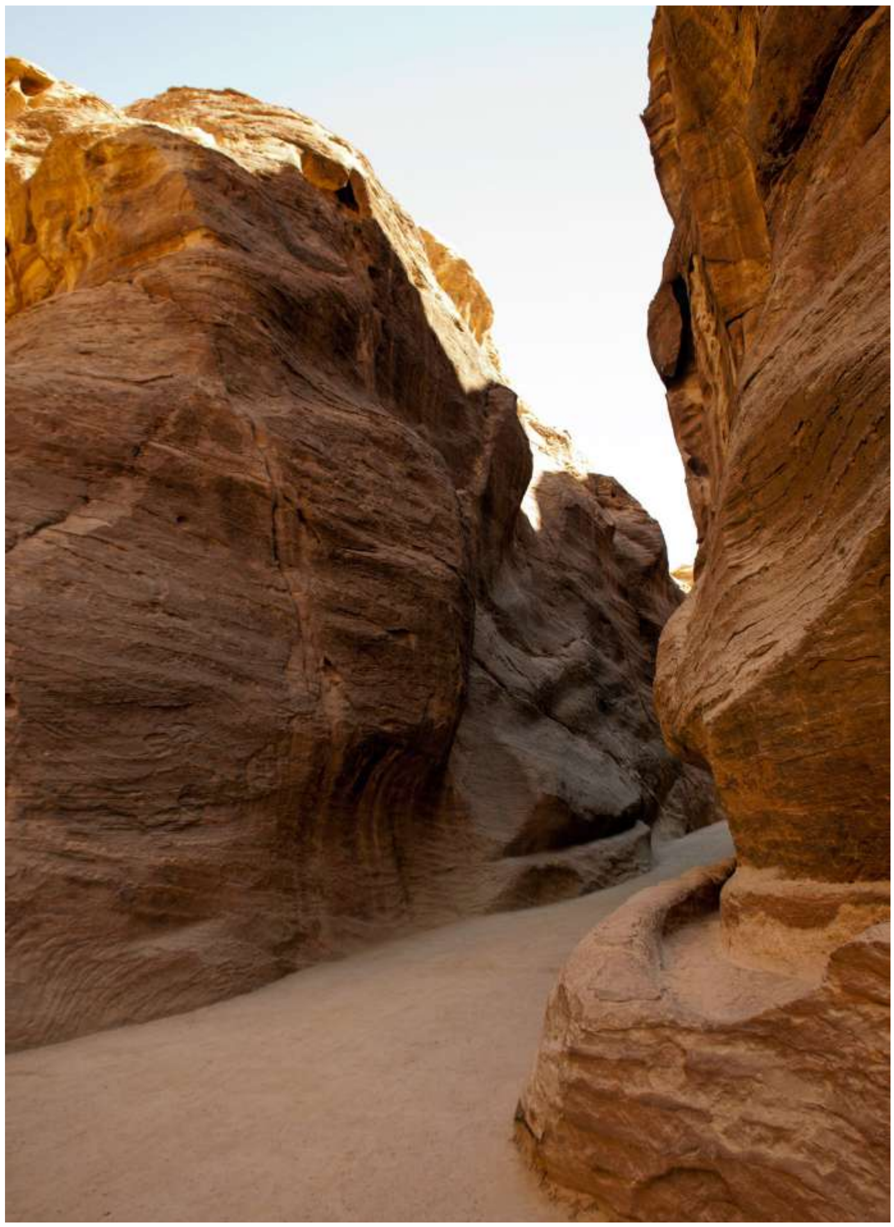
What is the Richat Structure and how did it form?

It might look like the site where a massive ancient meteorite once struck the side of the Earth, but this is no impact crater. The Richat Structure – also known as the Eye of the Sahara – is, in fact, a dramatic geological formation that appears like a giant bull's eye in the otherwise barren desert landscape. Located in the north African country of Mauritania, Richat is a hardened structural dome whose crest has worn away to expose the underlying layers of sedimentary rock and minerals.

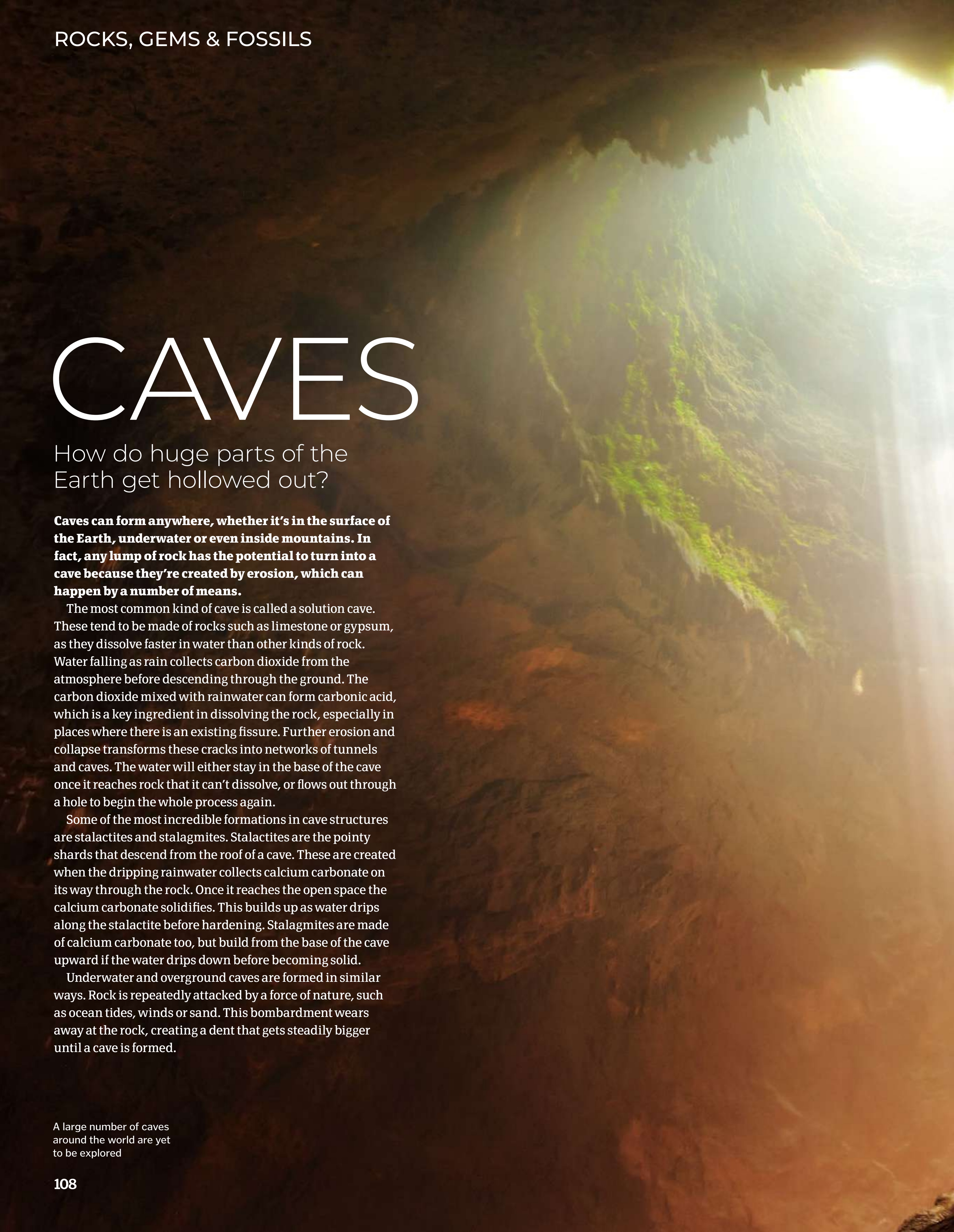
All sedimentary rock layers start out horizontal, but due to underground stresses they can get folded – either upwards in a convex shape (anticline) or downwards and concave (syncline). No one knows exactly why, but millions of years ago a circle of rock strata almost 50 kilometres (30 miles) across was uplifted causing an anticline dome to bulge up out of the Earth's surface. We now know this as the Richat Structure. Try thinking of the dome as the top half of an onion where each layer represents a different strata of rock.

Extremely slowly, the dome was eroded by the elements to expose a ring of concentric circles on the ground that are now clearly visible from space. Like the onion layers, these circles indicate the different bands of rock radiating out from the central limestone-dolomite shelf.

Richat's most visible bands of rock (or cuestas) are tilted ridges of resistant palaeozoic quartzite that slope away from the centre and gave it the misleadingly crater-like appearance that long confused scientists.



RIGHT
The Richat Structure is located in a remote part of the Sahara in Mauritania



CAVES

How do huge parts of the Earth get hollowed out?

Caves can form anywhere, whether it's in the surface of the Earth, underwater or even inside mountains. In fact, any lump of rock has the potential to turn into a cave because they're created by erosion, which can happen by a number of means.

The most common kind of cave is called a solution cave. These tend to be made of rocks such as limestone or gypsum, as they dissolve faster in water than other kinds of rock. Water falling as rain collects carbon dioxide from the atmosphere before descending through the ground. The carbon dioxide mixed with rainwater can form carbonic acid, which is a key ingredient in dissolving the rock, especially in places where there is an existing fissure. Further erosion and collapse transforms these cracks into networks of tunnels and caves. The water will either stay in the base of the cave once it reaches rock that it can't dissolve, or flows out through a hole to begin the whole process again.

Some of the most incredible formations in cave structures are stalactites and stalagmites. Stalactites are the pointy shards that descend from the roof of a cave. These are created when the dripping rainwater collects calcium carbonate on its way through the rock. Once it reaches the open space the calcium carbonate solidifies. This builds up as water drips along the stalactite before hardening. Stalagmites are made of calcium carbonate too, but build from the base of the cave upward if the water drips down before becoming solid.

Underwater and overground caves are formed in similar ways. Rock is repeatedly attacked by a force of nature, such as ocean tides, winds or sand. This bombardment wears away at the rock, creating a dent that gets steadily bigger until a cave is formed.

A large number of caves around the world are yet to be explored

© Getty

SAND

Discover the many minerals that determine the colour of our beaches and deserts

Whether it's between your toes or sculpted into a magnificent castle, sand is made up of lots of different components.

The most common are minerals from rocks, which are broken up by a process called weathering. Wind, rain and the freezing and thawing of ice all chip away fragments of the rock and shape them into fine grains of sand. Therefore, the type of sand you find is often determined by the types of rock nearby. However, if you're on a tropical beach then the sand is likely to also contain the shells and skeletons of sea creatures, which have been eroded by the waves and washed up on the shore.

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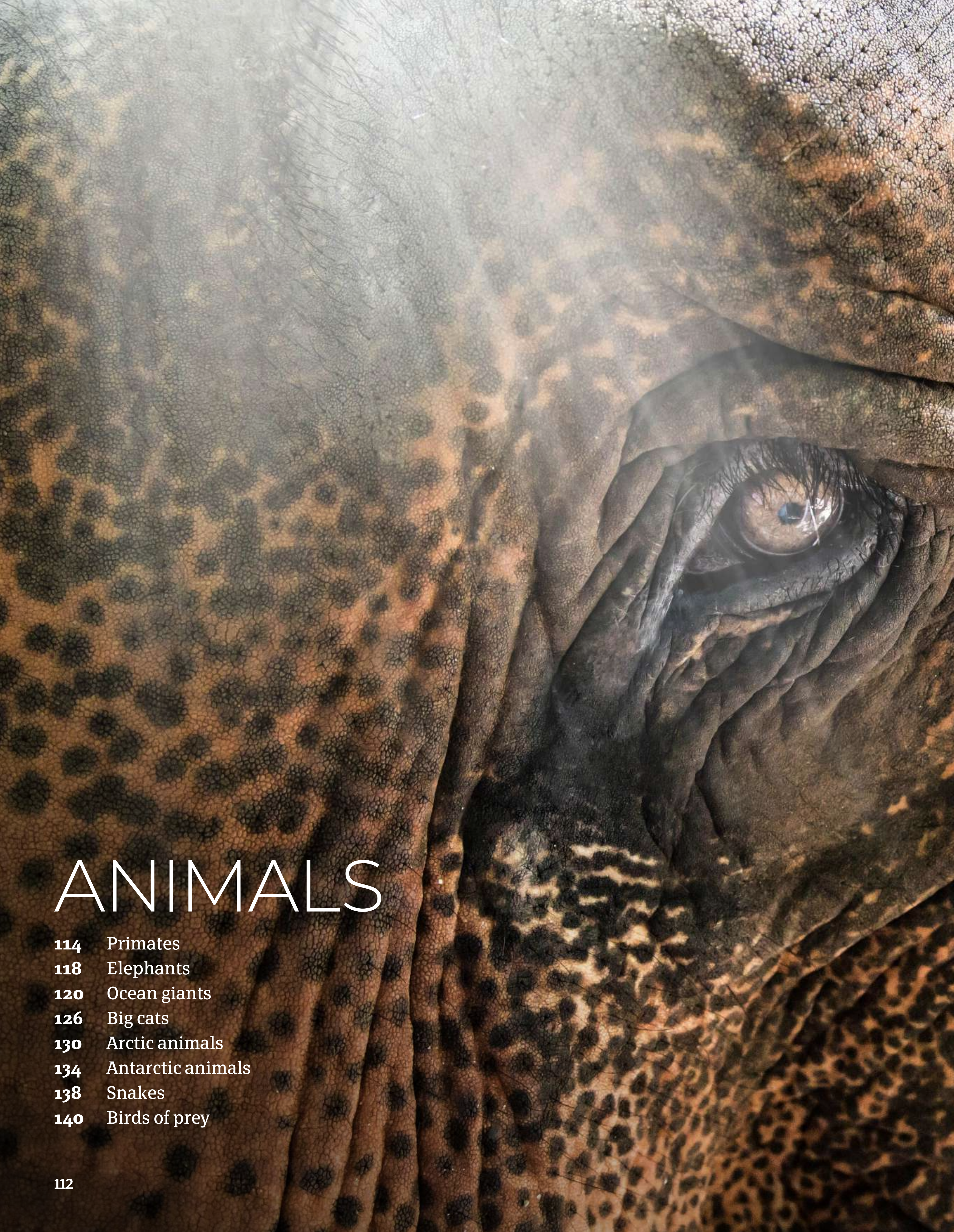
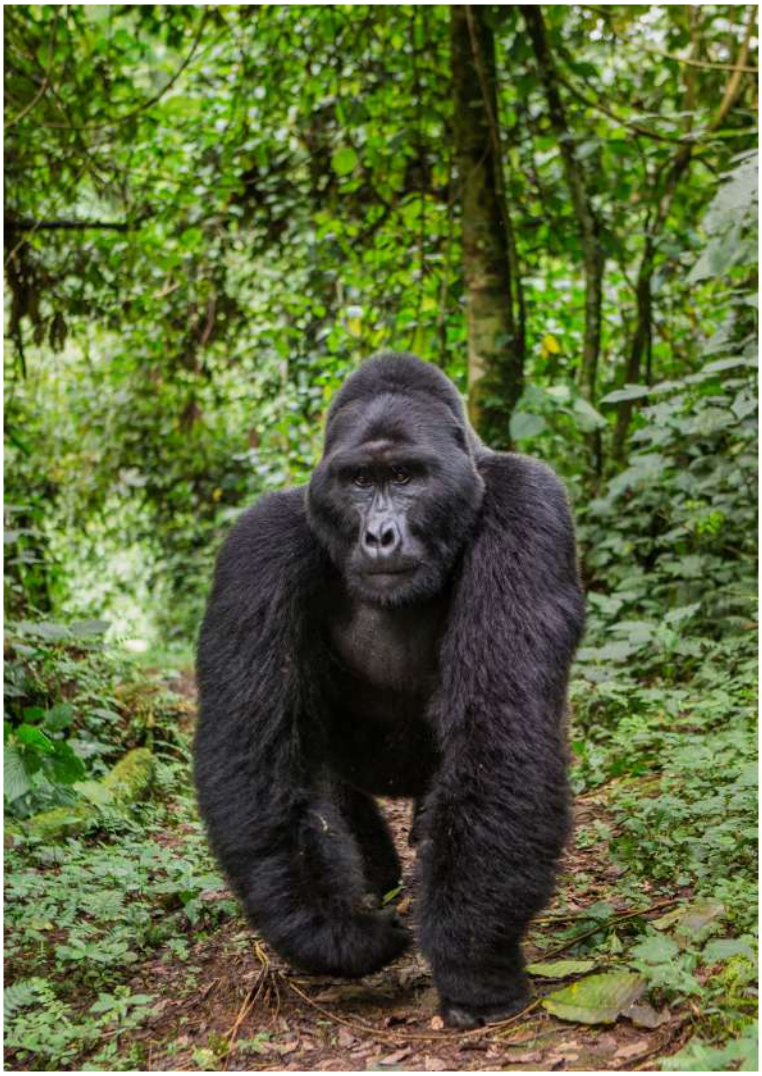


ANIMALS

PRIMATES

There's more to primates than apes, but they're a good place to start. This diverse group also contains some strange and very specialised animals – including humans



“THERE ARE 424 SPECIES OF PRIMATE CURRENTLY KNOWN, MOSTLY LIVING IN THE MIDST OF TROPICAL RAINFORESTS”

LEFT
Orangutans live most of their lives in trees and primarily eat fruit

ABOVE LEFT
Over 1,000 mountain gorillas live in the wild but the number is growing

ABOVE RIGHT
A group of monkeys is known as a troop

Primates are mammals with grasping hands and feet, unusually good vision and large brains for their body size. They evolved from squirrel-like tree-dwelling animals around 65 million years ago, just before the dinosaurs became extinct. Primates are divided into the lemurs (who live exclusively in Madagascar), lorises, tarsiers and simians. Somewhere between 33 and 70 million years ago, a few simians made the epic journey from Africa to South America, probably floating on impromptu rafts of vegetation. From there, they evolved into the New World Monkeys, and fascinatingly, they are the only primates native to that continent. The intrepid simians left behind became the Old World Monkeys – who have tails – and the apes – who don’t.

There are approximately 424 species of primate currently known, mostly living in the midst of tropical rainforests. Primates are very successful mammals. Even ignoring the fact that the dominant species on Earth (homo sapiens) is a primate, this group of animals has spread across the tropical regions of the world; from the humid forests of Central America to the arid African savannah, and from the swamps of the Congo basin to the Ethiopian highlands, a massive 5,000 metres (16,000 feet) above sea level.

Primates account for as much as 40 per cent of the fruit-eating animals (by weight) in tropical rainforests and their preferences have had a major impact on the evolution of plants there. Bananas and oranges, for example, use monkeys to spread their seeds and so have evolved skins that are very hard to peel unless you have opposable thumbs.

Primates live longer than other mammals of the same size, partly because they are often able to co-operate to defend themselves against predators. They also reproduce more slowly though, with infants hugely dependent on their parents for much longer than most other animals. Their reasonably large brains require time to fully develop, reaching their maximum potential. Once mature, their brains are filled with knowledge about their environment and its numerous dangers.

Although most primates eat fruit as part of their diet, many of them have specialised for other foods as well. Lemurs eat leaves, marmosets strip tree bark to eat the gum underneath and the aye-aye has an elongated middle finger to winkle insects out of trees, like a woodpecker.

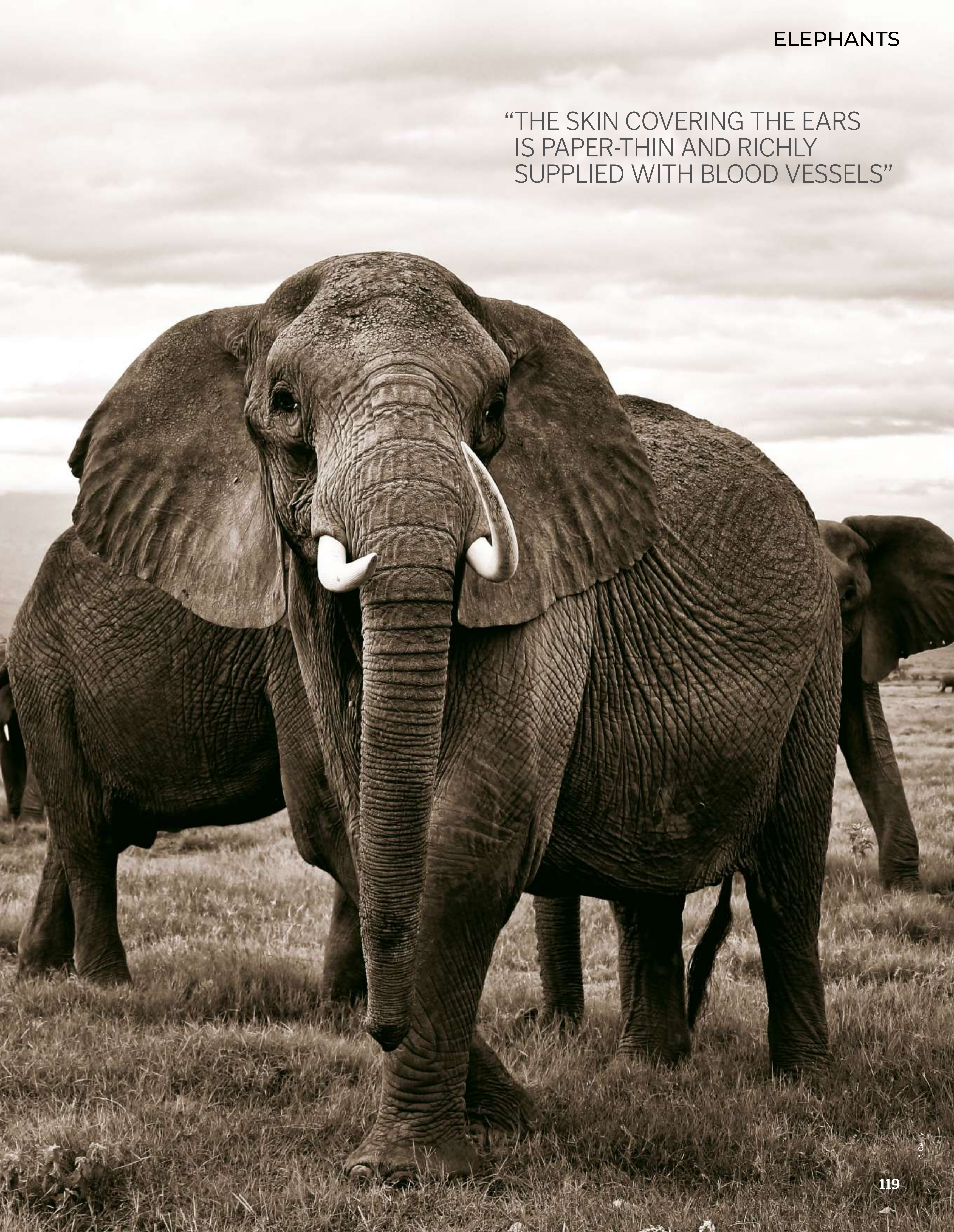
ELEPHANTS

Elephants are big in every sense of the word, but they are also surprisingly sensitive animals

Elephants are the largest land animals in the world, with African males averaging five tons. They have evolved to this huge size to protect themselves from predators but almost everything that makes an elephant unique is a consequence of this bulk. Large mammals don't have enough skin surface area to shed excess body heat so elephants have large flapping ears to act as radiators. A heavy head precludes a long neck so elephants have evolved a trunk, both to stretch up into branches and to be able to reach down to the ground to drink.

Most mammals stand with their leg joints half bent, which makes it easier to accelerate from a standstill. Elephants can only support their body weight by keeping the bones all in a line, like a pillar. Humans are the only other animal that does this. Elephants do not have fused ankle joints, as some people think, but it is true that they do not jump. The impact stresses would risk serious injury if they tried. This is the same reason that elephants don't gallop. Instead, they have a curious half-jogging gait where the front legs run and the hind legs walk fast.

Elephants used to be classified as pachyderms and lumped with the rhino and hippopotamus. Scientists now place them in their own order, the proboscidea, along with the extinct mammoths. There are three species of elephant living today: the African Bush elephant, African Forest elephant and the Asian elephant. All elephant species are protected, but poaching is a very serious problem.



"THE SKIN COVERING THE EARS IS PAPER-THIN AND RICHLY SUPPLIED WITH BLOOD VESSELS"

© Getty

OCEAN GIANTS

Real-life sea monsters so gigantic, they dwarf the dinosaurs

>

LEFT
Humpback whales can live in groups for years or even a lifetime

ABOVE
Killer whales lift their bodies out of the water in order to breathe

"THE HUNGRIEST CREATURES IN THE OCEAN ARE THE INSATIABLE KILLER WHALES"

The open ocean is an extremely dangerous place to live. There are no trees to hide in, no burrows you can dig. Death surrounds you in three dimensions and everything larger than you is a predator. To survive, you have to think big. For some species, this means living as part of a large school of fish. For others, it means actually becoming genuinely, truly enormous. Tiny fish are eaten by small fish. Small fish are eaten by larger fish and so on. In every size bracket, natural selection favours the larger animal over the smaller one. Over millions of years, animal species tend to grow gradually larger and larger until they are too big to fit in anyone's mouth.

Being big is easier in the sea than on land because the buoyancy of water supports an animal evenly around its body, instead of just through the soles of its feet. An African elephant, for instance, can't grow much larger than ten tons without fracturing its own legs. A blue whale, meanwhile, will weigh this much before it's three months old.

Sea giants can get by with much smaller skeletons, and their bones don't need to be as strong because they're not subject to so much shock loading. But the density of water also presents some challenges. It's much harder to move through water than air, so streamlining is essential. A blue whale is 60 times longer than it is wide, compared with only 3.5 times for a hippo. The rear third of the whale's body provides the muscle to drive the 7.5-metre (25-foot) tail fluke up and down. Why does an animal with no natural predators need to cruise at 32 kilometres (20 miles) per hour? One reason is that it makes it much harder for barnacles to attach. It's ironic that an animal as large as a whale should be threatened by something as small as a barnacle, but if enough take hold, the extra drag drastically increases the energy required to swim.

Food is the limiting factor for all large sea creatures. Light doesn't penetrate far in water so there are no grassy plains for large herbivores to graze. Instead the ocean is a thin soup, with the occasional chunk of meat bobbing in it. You can chase after the chunks, but catching them requires more energy, which means you need more food and so on.

The largest animals in the sea have found it is more lucrative to swallow the 'soup' instead. This is a mixture of unicellular organisms, fish larvae and shrimp, ie plankton. They are too small to swim against the current, so it's just a matter of straining them from the water. The lion's mane jellyfish can do this while expending virtually no energy. It swims slowly up by pulsing its bell and then relaxes to drift down again like a parachute. As it does, its tentacles billow out like hair to cover a wide area and prey gets speared by its stinger cells. Most large whales, along with the whale shark and the manta rays, adopt a slightly more active strategy by either swimming at speed into a dense cloud of plankton or

"SHARKS TREAT THEIR TEETH AS DISPOSABLE WEAPONS AND CAN LOSE A COUPLE WITH EVERY BITE"

taking huge gulps to suck them in, and then filtering them through a mesh of fibres made from modified teeth or gill bars. Different animals have different sized filter meshes that trap a particular size of plankton. Whales and whale sharks trap only the relatively large krill (a kind of shrimp) and crab larvae. Half a ton of krill contains about 450 thousand calories – which is about a tenth as much as a ton of chocolate – and an adult blue whale needs 3.5 tons of krill a day.

Very large animals need to protect their young to give them time to grow big enough to fend off predators. Whales are mammals so the embryo develops inside its mother to protect it. Great white sharks and manta rays have abandoned the usual fishy strategy of laying eggs on the seabed and copied mammals; the eggs are retained inside the female and hatch as live 'pups'. The mating and birthing of the whale shark has never been observed, but they are believed to use the same technique. Even the giant Pacific octopus will guard her nest of eggs until they hatch. Her month-long vigil is the last thing she does, though, because the exertion kills her – to compensate she lays around 100,000 eggs in one go!

Huge fish have other tricks normally reserved for mammals too. Large sharks and manta rays have a low surface area compared to their body size so they don't lose as much heat. This makes them effectively warm-blooded and allows them to maintain a more active lifestyle even in colder seas.

The best-studied ocean giants are those that live in fairly shallow water – above 200 metres (656 feet) – where most of the plankton is. But there are very large animals including squid that live in the perpetual blackness beyond. If you are an air-breathing mammal like a sperm whale that feeds on these squid, you face a unique challenge. To feed you need to dive to depths of up to three kilometres (1.9 miles), but to breathe you need to return to the surface. The pressure change in a round-trip is almost 300 atmospheres! Sperm whales have three times more myoglobin in their muscles to store more oxygen and their ribcage is flexible so that the lungs collapse under pressure and reduce the amount of nitrogen that dissolves into the blood. Despite this, the skeletons of older whales show pitting from the decompression effects of repeated dives.

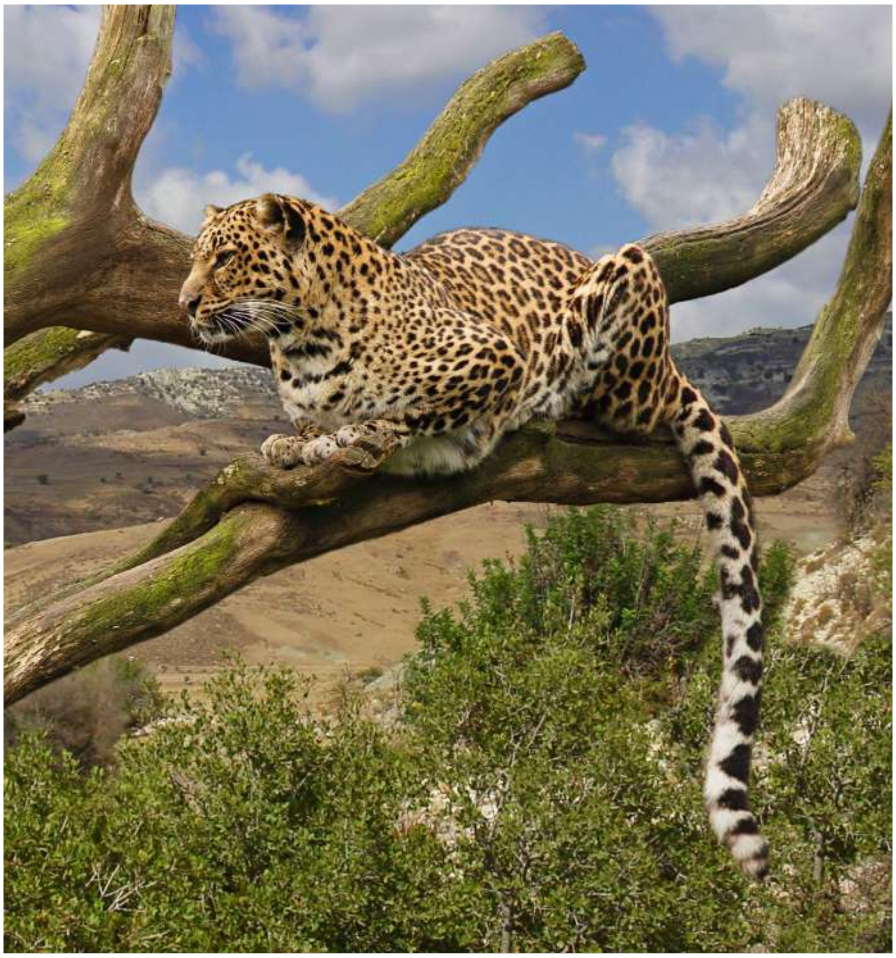
ABOVE RIGHT
Manta rays grow to over six metres (20 feet) wide, or even larger

BOTTOM RIGHT
The lion's mane jellyfish is the largest species of jellyfish known today

FAR RIGHT
Dolphins travel in groups of up to a dozen, and will help any injured members

BIG CATS

What makes these beautiful creatures such consummate experts in the business of killing?



"THE BIGGEST THREATS TO BIG CATS ARE HABITAT LOSS DUE TO HUMAN EXPANSION AND POACHING"

The big cats aren't a single biological grouping. It's an informal term that includes the lion, tiger, jaguar and leopard (sometimes called the Great Cats), as well as the cheetah, cougar, snow leopard and clouded leopard. That said, the three kinds of leopard actually belong to three different genera and aren't very closely related, despite looking quite similar. Nonetheless, big cats are all apex predators that hunt large mammals using their excellent camouflage to keep hidden, and powerful muscles to catch and dispatch their prey.

An antelope runs on the very tips of its feet, which allows it to have a much longer stride and means it is very fast. Cats can't do this because they have claws instead of hooves, and they need to retract them to keep them sharp. To catch hoofed animals, the big cats must run with their entire spine flexing to help elongate their effective stride. It's a very energetic technique, though, and cats can't run fast for long distances. This in turn pushes them to be stealthy in the approach and brutal in the attack. Where a wolf will bite and retreat as it waits for its prey to bleed to death, a cougar will leap onto the back of its prey and crunch straight through the spine with a single bite.

The roar of a big cat is a sound made by the walls of the specially elongated larynx vibrating as the cat exhales, but not all big cats can do it. The cougar, cheetah and snow leopard have no roar, but they do make a variety of other noises, including chirps, screams and growls. All of the big cats are able to climb trees. Leopards are the strongest climbers; indeed, an adult male can haul a young giraffe almost six metres (20 feet) into a tree. This skill enables big cats to protect their kills from hyenas and other pack scavengers that might steal them.

It's easy to think of animals this magnificent in terms of being 'perfectly adapted', but in fact hunting large animals for prey is incredibly difficult and all apex predators hover perpetually close to the brink of extinction. If they were anything less than brutally fit, they simply couldn't survive at all in the wild.

LEFT
Tigers often stay in ponds and lakes to keep cool and hunt prey

ABOVE LEFT
Leopards rest for most of the day in trees and on tall rocks, and hunt at dusk

BOTTOM LEFT
Some big cats are solitary animals, but others such as lions are very sociable

ARCTIC ANIMALS

Explore a strange frozen world and meet the wide variety of wildlife that calls it home

The Arctic is about as alien an environment as any non-native human will encounter on Earth. At the North Pole, days and nights last for six months at a time, temperatures can plunge to below -50 degrees Celsius (-58 degrees Fahrenheit) and there's no land for hundreds of miles. Instead, it's sheer white as far as the eye can see as a 14-million-square-kilometre (9.3-million-square-mile) sheet of thick ice stops you from getting your feet wet in a perpetually ice-capped Arctic Ocean that's never warmer than -2 degrees Celsius (28.4 degrees Fahrenheit). The skies often ripple and literally glow with the spellbinding iridescence of the aurora borealis – surreal waves of light caused by high-energy particles colliding with our atmosphere, sun haloes and mirages. Meanwhile, even weirder acoustic phenomena can be caused by the cold, dense air and hard ice, allowing conversations or otherwise inaudible sounds to be heard up to three kilometres (1.9 miles) away.

But along the continental landmasses that nudge above the geographical Arctic Circle and across the sea ice, a huge variety of highly specialised plants and animals still call this harsh region of the world home. They thrive here in a carefully balanced, interdependent ecosystem where the classic food chain hierarchy isn't as transparent as it seems.

At the apex is the polar bear, whose blubbery prey in the form of seals, walruses and even whales become trickier to catch in the summer when the ice retreats. In this lean season, everything edible becomes fair game for the world's largest land meat-eater, including birds, berries and seaweed. Filling out the predator niches below the polar

"DESPITE THE RISK OF BECOMING AN ENTRÉE, THE ARTIC FOX WILL FOLLOW POLAR BEARS IN THE HOPE OF A FREE MEAL"

ABOVE
Arctic wolves have two layers of fur to keep them warm in the harsh cold

TOP RIGHT CLOCKWISE
Snowy owls are one of the only species of owl to be active during the day

Reindeer thrive in the North American and Eurasian tundra

The majority of walrus herds are found along Eastern Siberia

Harp seals spend most of their time swimming and occasionally rest on ice

bear are smaller carnivores like the Arctic fox, snowy owl and wolverine, which will all scavenge on leftovers as well as hunt their own food. In fact, despite running the risk of becoming an entrée itself, the crafty Arctic fox will often follow polar bears in the hope of a free meal.

Lemmings are incredibly important to the whole ecosystem. Their population fluctuates from low to enormously high in a regular cycle: at their peak, as well as directly feeding the upper echelons of predators in the food chain (which time the rearing of larger broods of young to this abundance of food), they strip the summer tundra of seeds and grasses. The proliferation of their faeces is devoured by invertebrates, bacteria and fungi as well as fertilising the soil for the next generation of flora. As a result, summer brings swarms of insect prey for insectivores like larks and waders, which in turn feed owls, falcons and other avian predators. Then, when the lemmings can no longer sustain their numbers, the population crashes as predation and disease take over, and the land can recover.

The climate is typically cold and dark, with long, freezing winters and short, cool summers. The range of temperatures in the Arctic Circle is huge compared to elsewhere, from winters that average -40 degrees Celsius (-40 degrees Fahrenheit) to hot summer highs of 30 degrees Celsius (86 degrees Fahrenheit) plus in places. But it is getting warmer: summer 2012 saw major melting of the Arctic ice cap, with less than 50 per cent of the average summer ice coverage from 1979-2000. Some scientists predict that by 2050, the Arctic ice will melt completely in the summer. The repercussions of this go without saying, but we shouldn't jump the gun: these records only go back to 1979, so any doomsday predictions should definitely be put on ice for the time being.

ANTARCTIC ANIMALS

Despite the sub-zero temperatures, biting winds and unforgiving terrain, Antarctic animals survive against the odds

"THE ANIMALS THAT MAKE ANTARCTICA THEIR HOME HAVE TO BE RESILIENT, ADAPTIVE AND WELL INSULATED!"

The adaptive techniques that animals use to survive the temperature changes in their environment are nothing short of extraordinary. Some creatures such as Arctic ground squirrels or brown bears choose to while away winter in a deep slumber, while others like caribou or Arctic terns embark upon epic migrations to warmer climes the moment things get chilly. Then there are the hardcore stay-putters, the animals that have evolved some truly wonderful – and some downright weird – ways to weather the storm. Take the Arctic tundra's musk oxen, for example; this grumpy beast has a shaggy coat made of hollow hair for warmth that hangs so low to the ground that it traps a layer of warm air beneath the animal. Couple this with a whole herd of huddling musk oxen and things get very toasty indeed.

Physical adaptation is a key weapon against the cold. Animals such as many rodent species will bulk up during the summer months in order to have sufficient fat reserves to see them through the winter. Other animals, like Arctic foxes or hares, have developed thick fur that changes colour with the seasons to provide warmth and camouflaged protection.

Metabolic changes allow survival against all odds, as well as amazing chemical adaptations, like the icefish, which has antifreeze literally running through its veins.

However, surviving the chill isn't all about adapting to seasonal changes. There are some animals in ecosystems such as the deserts that have to survive the daily extremes of day-to-night temperature fluctuations, and have developed incredible methods of coping with both extremes.

At the very bottom of the Earth, life is tough. The animals that make Antarctica their home have to be resilient, adaptive and most of all, well insulated! Food is also a key factor, and so many of Antarctica's residents are highly adapted for hunting, because keeping warm requires a lot of energy! Seals wrapped up in blubber are able to withstand the icy chill of the seas and many seabirds live on the richly stocked islands surrounding the South Pole, with many more visiting seasonally to breed or feed. Even the majestic emperor penguin has some incredible means of surviving the harshest of winters, serving as living proof of nature's relentless policy of 'adapt and overcome!'

LEFT
A king penguin chick stays with its parents for a month to keep it warm

BOTTOM
Sea lions rest on an isle near Argentina while albatrosses fly over

SNAKES

Slither this way to learn everything you need to know about these stealthy serpents

In general, snakes get a bad rep. They are animals that are traditionally treated with suspicion, as sly and cunning creatures. The truth is, they are both those things. But they're also remarkable animals with amazing defences and incredible adaptations. Their ability to be some of the scariest animals on our planet without even having legs is no mean feat!

It's not clear exactly when snakes evolved in their current form, but scientists do believe that their ancestors were four-legged, lizard-like creatures. A fossil dating back 113 million years is thought to be the most primitive ancestor of the modern-day snake, and has a serpentine body but with the addition of four tiny legs. From these humble beginnings, snakes have conquered most environments on Earth, and range from the colossal, water-dwelling, constricting leviathans – such as the Amazonian anacondas – to the tiny, noodle-like threadsnakes. The UK has only three native snake species, and the adder is the only venomous variety. This snake lives in rough, open countryside, but there's no need to worry – it's pretty shy, and no one has died from an adder bite in more than 40 years.

Snakes have an affinity for water, and all snakes can swim. Some species are better at underwater life than others, such as sea snakes that can stay submerged for an hour or more. Despite their aquatic surroundings, these snakes can't drink seawater, and can go for months without drinking fresh water. It's proposed that they rehydrate with fresh water when heavy rains fall over the ocean.

The majority of snake species aren't venomous, but for those that are, this is as much of a defence mechanism as it is a hunting tool. Each venomous snake species has its own special toxic cocktail of venom, containing a mix of proteins and enzymes designed to immobilise both predators and prey. Some venom works by attacking the nervous system; others by causing viscious damage to blood and tissue.

Some species possess a sixth sense: the ability to detect heat signatures and see in infrared. This, coupled with their supreme strength, agility, venom and lightning-fast reflexes, means that a snake's prey doesn't really stand a chance.

The African bush viper is a venomous tree snake found in Central Africa

© Getty

BIRDS OF PREY

The fastest, the strongest, the most agile – meet the planet's most adept aerial assassins and learn how they survive

Some are manoeuvrable dog-fighting specialists, while others soar high above the ground like stealth bombers. They attack in the air, on the ground and in water. All of them are apex predators, adapted for life at the top of the food chain.

Birds of prey, also known as raptors, may look like feathered dinosaurs, but they're not any more related to them than any other bird. The physical resemblance comes from their shared carnivorous lifestyle. Most belong to one of two families: the Accipitrids include eagles, hawks, buzzards, kites, harriers and true vultures, while the Falconids consist of falcons, kestrels and falconets. There are also two families of owls and a few species, such as the osprey and secretary bird, that are in families of their own.

Raptors hunt in two main ways. The large Accipitrids and ospreys float high above the ground while they scan for possible targets using their extremely acute vision. They will then dive-bomb or circle around to strike silently and suddenly. Eagles prefer to snatch prey and keep flying to minimise the time they spend vulnerable on the ground. Sea eagles, such as the bald eagle, use this technique to catch fish swimming close to the surface. Ospreys, which hunt in freshwater as well as the sea, can spot fish under the surface while flying as high as 40 metres (130 feet) above the water. They drop feet first, and will completely submerge in pursuit of the kill. Uniquely among raptors, ospreys have nostrils they can close to keep water out.

Falcons and hawks hunt other birds in the air. The peregrine falcon attacks pigeons and water birds from high above, dive-bombing – or stooping – from 4.8 kilometres (three miles) up so that they accelerate to over 320 kilometres (200 miles) per hour. At this speed the increased air pressure is enough to burst their lungs, but peregrines have small bones in their nostrils called tubercles that divert most of the airflow to the sides. While the peregrine is technically the fastest animal in the world, falling isn't the same thing as flying. The fastest in level flight may be the Eurasian hobby, which actually chases down speedy swallows and swifts.

Species that can't compete in speed rely on their superior agility, like the forest falcons. These sit patiently in dense forest areas, using their extremely sensitive hearing to listen for birds flying nearby. When one passes close enough they will launch into a short and dangerous slalom run through the branches to catch the bird before it escapes. >

ABOVE
A great grey owl emerges out of the shadows and swoops down on its prey

RIGHT
The bald eagle is the national animal of the United States of America

"BALD EAGLES TAKE FOUR OR FIVE YEARS TO REACH SEXUAL MATURITY, AND USUALLY LAY ONLY ONE OR TWO EGGS PER SEASON"

Falcons use their beak as a weapon, and some even have a tooth on the upper beak that they use to snap the spine of their prey. For most other raptor species, though, the beak is only used for tearing chunks of flesh from an already downed victim. To kill, they rely on their talons. The exact shape of these depends on the type of animal they hunt: owls have short, heavily muscled toes to squeeze the breath from mice and small mammals, with thin, straight talons to hold them still; while eagles and buzzards have longer, curved talons on the backwards-facing toe and the first forward-facing toe for a powerful pincer grip. The osprey can even rotate its talons so that two toes face forward and two back to hold on to wriggling fish.

Vultures and condors have the weakest talons of any raptor, because their diet consists almost entirely of carrion. Vultures have bald heads to make it easy for them to plunge their entire head into the carcass of a large animal without the blood getting on their feathers.

Judging which is the biggest bird of prey isn't easy. The Andean condor has the largest wingspan at up to 3.5 metres (11.5 feet) and the Philippine eagle the longest body at over one metre (three feet), while the heaviest is Steller's sea eagle in north-east Asia, which can weigh up to nine kilograms (20 pounds).

Because they have no predators, raptors tend to live a long time. Golden eagles last for 25 years in the wild and up to 46 years in captivity, and the Philippine eagle can survive for up to 60 years in the wild! But a long lifespan goes hand-in-hand with a slow rate of reproduction. Bald eagles take four to five years to reach sexual maturity, and usually lay only one or two eggs per season. Even when more than one egg hatches, in many raptor species the strongest chick will kill the others in the nest. This makes many raptors very vulnerable to population crashes from hunting or habitat loss. Around 120,000 Amur falcons are illegally killed by hunters every year in India as they migrate from eastern Asia to South Africa, for example.

There are success stories too though. Red kites have been reintroduced to the United Kingdom and Ireland, and fortunately peregrine falcons are no longer endangered in Britain now that organochlorine pesticides have been banned.



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